PHYSIOLOGICAL AND PATHOLOGICAL EFFECTS OF SEVERE EXERTION (THE MARATHON RACE).*

GENERAL OBSERVATIONS.†

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One of the decisive battles of the world was fought in the year 490 B. C. Miltiades, a Greek general, commanding an army of but 11,000 men, defeated the Persians, numbering over 100,000. The conflict took place on the plain at Marathon. After the battle a soldier was dispatched to carry the news of victory to Athens, a distance of 40 kilometers (24.85 miles). As he reached his destination, having run without stopping, and as he emitted the words, "Victory is ours," he fell dead.

In 1896 the Grecian government established the course covered by this unknown soldier as an official event of the Olympic games. America was not especially interested in this until an American youth, in 1908, won the race. Since then it has become popular on this continent; it has, in fact, become almost a craze with the American boys to train for and compete in these races.

It can easily be seen what a fertile soil for study the participants in this race could furnish and that such a study should produce facts of immense value toward determining, if possible, to our own satisfaction, the ever-recurring question as to the beneficial or harmful effects of such a severe exertion as this. Not only the visible immediate effects, but also the unseen remote effects must be seriously considered. This study includes observations upon youths and men from the various walks of life, already by far above the average in physical vigor, because they are the pick from large groups of men and boys scattered over our entire district.

At a time such as the present, when Marathon racing is so popular, and when it must be that many who are physically unfit enter into this sport, the thorough understanding of the effects of so severe a form of exertion as this is of the utmost importance. Toward this end, the Department of Physical Research of the Pittsburg Athletic Association devoted its inaugural undertaking to the study of the participants in the Marathon race of June 26, 1909.

*From the Department of Physical Research, Pittsburgh Athletic Association. Directed by WATSON L. SAVAGE, M. D.

†Presented, by invitation, before the College Gymnasium Directors' Society, at the Columbia University, December 31, 1909.

Up to the present there have been comparatively few observations upon Marathon runners. These observations, while they were made by most competent observers, in nearly all instances, were carried out upon small groups of men at irregular times and in each series they covered only a comparatively few phases of the entire subject. The reports of this work are referred to in the appended bibliography.

Nothing so determines the success or failure of such a series of observations as these, as the control that the observers have over the men and the discipline of the contestants. Having this, through the liberality and interest of the Association and the contestants themselves, we proceeded to carry out the following observations which may be classified under three headings:

(1) The general observations.
(2) X-Ray examinations.
(3) Observations upon the cardio-vascular and renal systems.

We compiled the following questions to be filled out by the contestants and later recorded the answers and our own observations on a card so as to have nearly all our information in condensed form. This makes such a work systematic and comparatively easy.

PITTSBURG ATHLETIC ASSOCIATION.

Report of Runners in Marathon Race June 26, 1909.

PHYSICAL EXAMINATION.

Date .....Hour.....	Date .....Hour.....	Date..... Hour.....
Before Race.	Immediately After	Subsequent Re-exams.
Height	.....	.....
Weight	.....	.....
Girth Chest Inf.....	.....	.....
Girth Chest Def	.....	.....
Girth Arm R.....	.....	.....
Girth Thigh R.....	.....	.....
Girth Calf R.....	.....	.....
Nutrition	.....	.....
Condition	.....	.....
Temperature:		
Mouth	.....	.....
Rectal	.....	.....

Heart:

Mitral .....

Aortic .....

Pulmonic .....

Remarks.

Blood Pressure Horizontal:

Pulse .....

Systolic .....

Diastolic .....

Blood Pressure Erect:

Pulse .....

Systolic .....

Diastolic .....

URINE ANALYSIS.

General.

Characteristics .....

Reaction .....

Sediment .....

Sp. Grav. .....

Albumin .....

Sugar .....

Acetone Bodies .....

Microscopic.

Casts .....

Cells:

Epeth. .....

R. B. C. .....

W. B. C. .....

Crystals .....

Remarks.

.....

.....

.....

Runner's No ..... Date .....

Name .....

Address ..... Telephone Number.....

Working hours..... .....to..... Age .....

Height .....Weight before training.....Weight now.....
Pulse rate morning before rising.....Pulse rate evening.....
Distance run on day of taking evening pulse.....
How old were you when you first began distance running?.....
How many times have you run Marathon races?.....
When did you last consult a doctor?.....
For what? .....
Doctor's name and address .....
Diet .....
Do you eat meat once, twice or three times a day?.....
What kinds of meat do you prefer and eat most of?.....
Do you eat slowly or fast?.....How much tea do you drink daily?.....
How much coffee do you drink daily?.....
How much milk do you drink daily?.....
How much water do you drink daily? ....
How much beer do you drink daily?.....
How much wine do you drink daily?.....
How much liquor do you drink daily? .....
How many cigarettes do you smoke daily?.....
How many stogies do you smoke daily?.....
How many cigars do you smoke daily?.....
How many pipes do you smoke daily?.....
Do you chew tobacco?.....Do you use drugs in any form?.....
Who trained you?.....
Write a full history of your training, giving distances and speed, as well as you can remember.

.....
.....
.....
What other athletic experience have you had?.....

Subsequent Report. *Date*.....

How far did you run on June 26?.....
What did you eat that day for breakfast?.....Time.....
For lunch?.....Time.....
For dinner? .....Time.....
What and how much did you drink on the day of the race?.....
What did you eat during the race?.....
What did you drink during the race?.....
Did you have any pains during the race?.....
What is your weight now in your running costume?.....

At what distance did you feel distress?.....
What is your pulse rate lying down?.....
How did you sleep after the race?.....
How do you feel since? .....
Do you have any impressions or sensations to report regarding the race?
.....
Do you expect to run the full distance again? .....
What is the weight of your running suit? .....

Remarks.

.....
.....
.....
.....

General Scheme of the Medical Examinations.

Having entirely within our power the making of the rules of the contest and the enforcing of them, we were enabled to control the runners, as has not been possible in previous observations. The usual course, 25 miles into the country and a run back, make it necessary to find limited quarters in which to examine the runners in the midst of excitement, confusion and noise, and then to transfer the examiners together with their instruments, over a distance of 25 miles to the finish. It is impossible this way to undertake certain desired records. We therefore planned a course, that should start from the club house, and pass this point four times, finishing at the starting point. This proved of exceeding value, as will be shown later.

The first circuit of the course was 3 miles, second circuit 8 miles, the third, 12.5 miles, and the fourth 1.35 miles, making the total distance 24.85 miles, the actual distance from the battlefield at Marathon to Athens.

Desiring to have some accurate heart and diaphragm measurements, arrangements were made at the West Penn Hospital where they have a very complete equipment for the making of fluoroscopic studies.

A letter was sent to all intended competitors, taking them into our confidence and telling them what we wanted to do, and asking for volunteers to report on Friday before the race for preliminary examinations; which examinations were much more extensive and complete than was possible on the morning of the race. Twenty-four men reported, and of this number 22 were taken to the hospital and placed before the X-Ray. On the morning of

the race, all contestants were ordered in at 11 o'clock and with the entire staff of assisting physicians present, thirteen in all, and three sets of instruments, we were able to get a thorough examination of all the starters, but, of course, could not undertake to send all of them to the hospital for X-Ray examinations, feeling that it was better that we should have a few thoroughly done than to undertake something that would prove a failure, because of its being more than we could accomplish.

As the men finished the race, those who had on the previous day been before the X-Ray machine, were immediately examined in the tents and put into an automobile and carried to the hospital for a second examination, which was usually accomplished in from fifteen minutes to an hour after the finish.

The tents that were erected, for dressing and for the examinations, were arranged in a group in which the dressing tents faced the large medical tent. This arrangement brought all the men together before the race, where their change of clothing, practically in the presence of the physicians, compelled them to come back to the same place for their clothing whether they completed the full distance or not. Here was a valuable factor, enabling us to examine very soon after quitting the run, those who did *not* finish the distance, affording an opportunity to make some of the most valuable observations in comparing the effect of running upon a man when in condition, and when not properly prepared for the run.

The running of the course in circles brought them back four times within easy distance of the examining tents, so that we were able to get those who quit under observation soon after their exertion had ceased, although in one or two cases they had to be brought in by automobile attendants. The arrangement of the tents also avoided confusion and noise.

The next important move was to offer prizes to all who finished within four hours, the condition being that they must pass both medical examinations, namely, before the race and after they had finished, otherwise, they could not qualify for a prize. This was the key which practically opened the door to the more complete series of observations that we were able to make, the consequence of which was as follows: Fifty-nine men entered for the run, one was disqualified before the race, 55 started; 29 completed the full distance; 20 failed to finish, but were examined by the physicians after their race and only six, most of whom did not complete, slipped by the examiners.

The Course.

In studying the course as shown in the chart it will be seen that it is a very hilly one and different from the usual Marathon

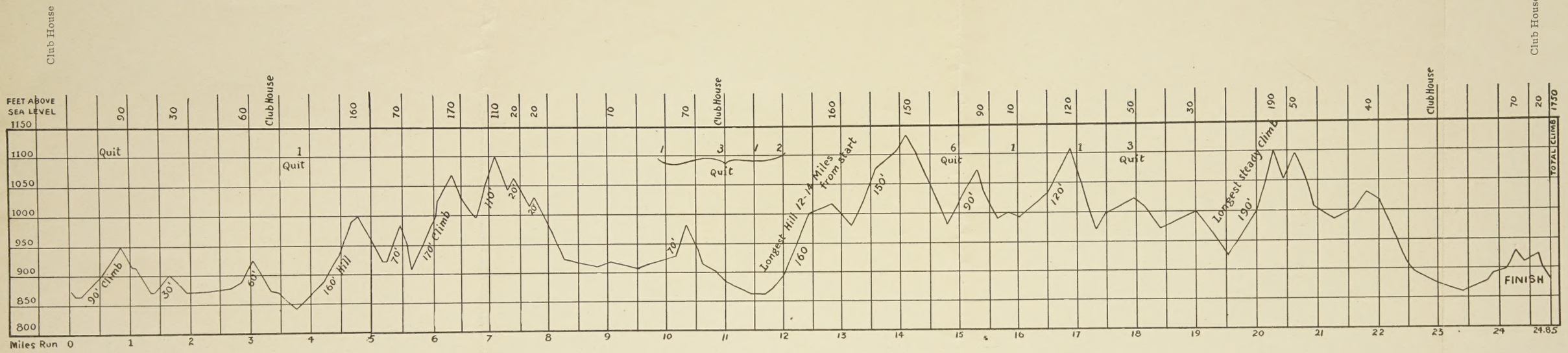


Diagram of the Course with Elevations.

courses which are laid out along some road leading to a city. The roads upon which many of the prominent Marathon runs have been held, are more nearly level or slightly down grade.

In this instance the hilly roads and the heavy downpour of rain, making asphalt pavements on a down grade treacherously slippery during the shower,delayed the runners, by making their task more difficult and lessening their rate of speed.

The chart clearly shows that the men fell out after climbing the hills at the fourth to seventh miles, at the eleven and one half to fourteenth miles, and after the sixteenth to seventeenth miles.

At the first climb, a total of 510 feet, seven of the runners seem to have become discouraged and quit when they reached the club house.

The second severe climb occurred at the twelfth to the fourteenth miles, a lift of 310 feet. Here six others came to grief.

At the sixteenth to seventeenth mile four more gave up. The others finished, but some of them came in after the time limit, having walked some of the distance.

Weather Conditions.

The weather report of June 26 was taken about three miles away and is herewith shown:

The barometric pressure from 2 p.m. to 6 p.m. averaged 29.13 inches, elevation 842 feet. A thunderstorm occurred from 1.10 p.m. to 3 p.m., advancing from the west. It was accompanied by a light rain in the downtown district of Pittsburg from 2.15 p.m. to 3.40 p.m., the amount of precipitation being 0.01 inch. The shower was moderately heavy, however, over Allegheny and some parts of Pittsburg. The hourly temperatures were as follows: 2 p.m., 82; 3 p.m., 70; 4 p.m., 71; 5 p.m., 73; and 6 p.m., 75. The highest wind velocity during the four hours was 19 miles per hour from the north during the 5 minutes ending at 2.50 p.m. The total wind movement during the hour ending at 3 p.m. was 12 miles; for the hour ending at 4 p.m., 6 miles; for the hour ending at 5 p.m., 3 miles; and for the hour ending at 6 p.m., 3 miles. For the hour ending at 3 p.m., the prevailing direction of the wind was from the north; at 4 p.m., northwest; at 5 p.m., west and at 6 p.m., southeast. The weather during the entire period was cloudy. We have no record of the humidity at those hours of the day, but it was probably higher than usual at those hours on account of the rain. Relative humidity at 8 a.m. was 73 per cent and at 8 p.m., 73 per cent.*

Temperature 82 degrees F. at start of race; humidity 73 per cent. About an hour after the race began, there was a heavy downpour which lasted for about an hour and drenched the runners. This was the undoubted cause, directly or indirectly, of several quitting as a result of falls and sore feet. It may also have been a factor to be considered in the temperature findings of those who did not finish the race.

* Records from local office of the Weather Bureau, Pittsburg, Pa., submitted by Henry Pennywitt to Dr. Savage.

Wind varied from a velocity of 19 miles an hour to 3 miles at time of finish.

Age.

The ages of the contestants ranged from 18 to 52 years, with the major portion under 23 years of age. The under-age limit was placed at 18 years. The greatest number at any single age was 18, while more than half of the contestants were 22 or under. One man at 52, although he did not finish, still thinks he can run the distance. Success in finishing does not seem to be directly controlled by age; three at 36, one at 35, one at 31 finished, while one at 52 and three at 29 failed.

Ages of the first eight men were as follows: 22, 22, 20, 18, 28, 31, 36, 18.

Number Quitting and Those Finishing the Race.

Quit	Age	Finished
3	18	5
3	19	2
2	20	2
2	21	3
1	22	4
2	23	1
	24	
2	25	2
	26	
2	27	2
	28	1
3	29	
	31	1
	35	1
	36	3
1	52	
21	Total Cases	27

Men past 40 should not try such long distance running, and the same holds true for those under 20. The most serious effects seem to have come to the man of 52 and to a boy of 18 years.

Height of Runners.

The general average of the entire series was 5 ft. 6.4 in., the greatest number being 5 ft. 7 in. The entire range varied from 5 ft. 2 in. to 6 ft. 2 in. The large men showed up well, both in number of cases and position at finish.

The first four men averaged 5 ft. 4 in., or 2.4 in. below general average.
The second four men averaged 5 ft. 9 in. or 2.6 in. above general average.
The third four men averaged 5 ft. 5 in., or .9 in. below general average.
The fourth four men averaged 5 ft. 7 in., or .3 in. above general average.

Height Ft.	Height In.	No. of Cases at Each Height
5	2	1
5	3	5
5	4	6
5	5	8
5	6	7
5	7	10
5	8	4
5	9	4
5	10	1
5	11	1
6	0	2
6	1	0
6	2	1

Total No. of cases, 50; average height, 5 ft. $6\frac{4}{10}$ in.; mean, 5 ft. 6 in.

Girth Measurements.

The general run of the contestants showed better developed lower limbs than of the upper body as would be expected.

Right arm.....average 10⅛ in.
Right calf.....average 13½ in.
Right thigh.....average 19½ in.

Girth Measurements.

In.	R. Arm	In.	R. Calf	In.	R. Thigh
8½	1	12		18	
8¾		12¼	1	18¼	1
9	1	12½	1	18½	1
9¼		12¾	1	18¾	1
9½	3	13	3	19	3
9¾	4	13¼	6	19¼	2
10	3 Ave.	13½	3 Ave.	19½	2
10¼	2	13¾	2	19¾	3 Ave.
10½	1	14	2	20	5
10¾	3	14¼	2	20¼	
11	3	14½		20½	2
11¼	2	14¾	2	20¾	1
11½		15		21	
				21¼	
				21½	1
				21¾	
				22	1

23 cases average 10⅛ in. | 23 cases average 13½ in. | 23 cases average 19¾ in.

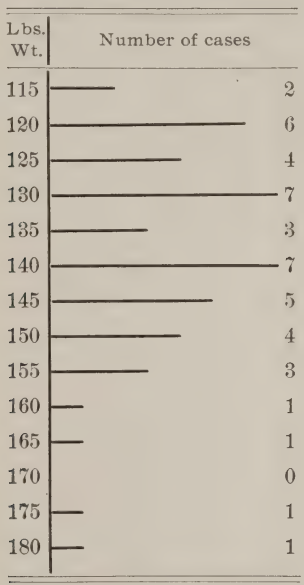
Chest Measurements.

The chest measurements seem to be small for this class of men. The comparison of those who quit to those who finish show a definite advantage with the better chest capacity.

Of the winners 7 were above average, 4 were below average.
Of the quitters 5 were above average, 6 were below average.

Weight.

While the average weight of the entire series was 140 pounds, the greater number were below that. Compared with the insurance standard weight for their relative height, they were, on the average, 3.6 pounds below weight, 32 cases being below weight on the average of 9 pounds, and 18 cases above weight, averaging 5½ pounds. In this last group there was one case 25 pounds overweight which greatly influenced the general average.



Total No. of cases, 45; average weight, 140.

Occupation and Working Hours.

The occupations, for the most part, were laborers, classed as light, medium and hard labor—coachmen, drivers, mill hands, etc.

The working hours correspond to the investigations made by the Pittsburg Survey. The greatest number worked 9 hours and the average 9½.

Habits.

In the main, the habits of these men seemed to be good, and indicate the general understanding that one, to win such a race, must take care of himself and must be temperate.

The table shows coffee to be the almost universal drink; then comes tea, 20; only 8 use beer; 1 liquor and he finished in fifth place. There were 9 who took no stimulants of any kind. Tobacco is generally cut out; about one third only using in any form and then always moderately. Ten drank great quantities of fluid, over 3 quarts a day, but they were mill men who perspire freely when at work. Out of 28 finishing 11 used tobacco; 4 out of the first 5 used tobacco. Of the 21 not finishing 8 used tobacco.

Occupation		No. of Men
Professional		1
Merchants		3
Clerks		5
Laborers	Light	7
	Medium	8
	Heavy	10

Working Hours Daily	No. of Men
5	3
6½	1
8	7
8½	1
9	10
9½	1
10	5
10½	6
11	1
12	5
13	
14	2
15	
16	1

Total No. of cases, 43; average hours, 9½.

HABITS.

DRINKING	
Coffee	31
Tea	20
Beer	8
Liquor	1
Wine	0
None	0
TOBACCO	
Chew	4
Cigars	2
Cigarettes	2
Stogies	7
Pipes	7

This was very interesting. Six were classed as vegetarians, one of whom was not permitted to run owing to a marked arrhythmia of pulse and generally poor condition. The other 5 did not quite hold their own with the meat eaters, 60 per cent finishing. The greater number ate meat once a day, and of them 65 per cent finished; out of the 10 who ate meat twice a day 70 per cent completed the race. Beef was by far the most popular meat.

DIET.

Meat		No. started.	No. finished.	Percentage Finished
	0	3	5	60%
Week	2		1	100%
Week	3	1	2	50%
Day	1	13	20	65%
Day	2	7	10	70%
Day	3	4	6	66⅔%
MEAT PREFERRED:				
Beef			21	
Veal			1	
Pork			4	
Lamb			2	
Any			5	

AGE OF BEGINNING TRAINING.

The study of the age of beginning distance running and apparent ability to complete the distance shows the greatest per cent of failures in those who began training at eighteen or under. This may be due to their incomplete preparation, but more than likely it is due to the fact that their organs had not yet reached sufficient development at this time of their natural growth and maturing years to withstand so severe a strain as this form of sport demands.

Age of Beginning Distance Running.

Quit	Age	Finished
	12	1
	13	1
	16	
2	17	4
5	18	4
1	19	2
3	20	2
2	21	4
1	22	1
1	23	1
1	24	2
2	25	1
1	26	
1	27	2
2	29	
	31	1
	35	1
	36	1
1	52	
23	Total Cases	28

Distance Run in Training.

Miles	
2	2
3	4
5	3
8	1
12	3
13	1
18	1

15 cases: average 7 miles.

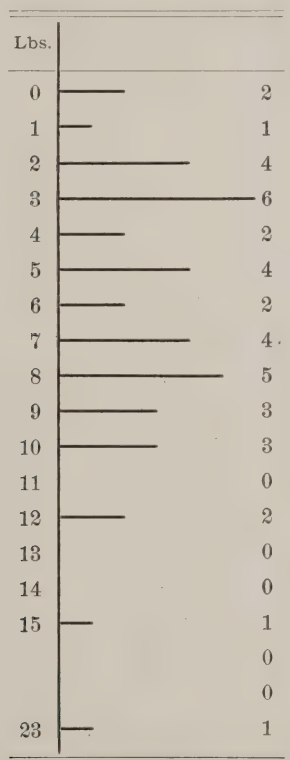
Distance Run in Training.

This question does not seem to have been well answered, for what reason we do not know. Only fifteen gave this information, and their average daily run was seven miles.

Weight Lost in Training

The general average was 6.4 pounds, one man losing as high as 23 pounds, and another 15 pounds. Both of these were six-foot men.

Weight Lost in Training.



40 cases; average $6\frac{4}{10}$; mean 6.

WEIGHT COMPARED WITH STANDARD WEIGHT FOR HEIGHT.

Fifty cases—average loss 3.6 lbs.

Lbs. Below Wt.	No. Cases
1	
2	3
3	1
4	2
5	2
6	3
7	2
8	1
9	5
10	1
11	2
12	2
13	2
14	3
16	1
18	1
21	1

Total cases below weight, 32; average 9 lbs.

Lbs. Above Wt.	No. Cases
1	3
2	2
3	1
4	0
5	3
6	4
7	0
8	3
	0
12	1
	0
25	1

Total cases above weight, 18; average 5½ lbs.

NUMBER RUNNING PREVIOUS MARATHONS.

Our information on this point is interesting. The fact is that it is a new sport in this vicinity and nearly all of the races in which these contestants had participated had been run within a year. There were only five out of the entire series who had not tried this distance before.

14 had run once before.
12 had run three times before.

Success and failures seem about the same, as both average two runs.

Never run	5 out of 6 finished.
One run	9 out of 15 finished.
Two runs	3 out of 8 finished.
More than two	11 out of 20 finished.

It would seem from this table that in this class of athletes the first run is the best and after they had run three times they either quit as failures or continue as the survivals of the fittest. How much is due to the effect of the severity of this form of athletics is an open question. It does seem that the race can injure and incapacitate the inexperienced runner.

Number Running Previous Marathons.

Times Run	No.
0	5
1	14
2	7
3	12
4	5
5	3
6	
7	
8	2

Loss of Weight During the Race.

Lbs.		
0	2	
½	1	
1	5	
1½	5	
2	6	
2½	2	
3	3	
3½	5	
4	6	
4½	3	
5	1	
5½	2	
6	1	
6½	1	
7	1	180 lbs.
7½		
8		
8½	1	170 lbs.

Total number of cases, 42; average loss, 3.1 lbs.
Men who lost most were overweight, or large men.

Loss of Weight During the Race.

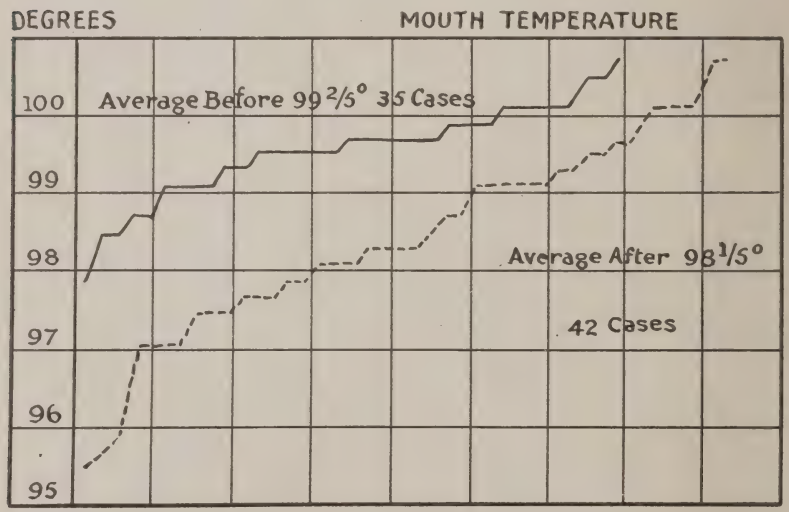
It was difficult to get this accurately, as the rain had soaked their clothing, and there was also a large variation in the weight of clothing worn. We tried to get it from the answer to the question regarding the weight of suit in the questionnaire, and then to allow for the amount of moisture it contained, but it seems that the question was not accurately answered in all cases.

The table shows a variation from nothing to 8.5 pounds, with an average of 3.1 pounds, the greater losses occurring in the large men who weighed 170 and 180 pounds.

Some ate and several drank during the race, thus also influencing the body weight.

Temperature.

The observations upon the temperature proved a very interesting study, but unfortunately we cannot calculate the influence of the rain upon the runners, especially upon those who quit soon after the rain.



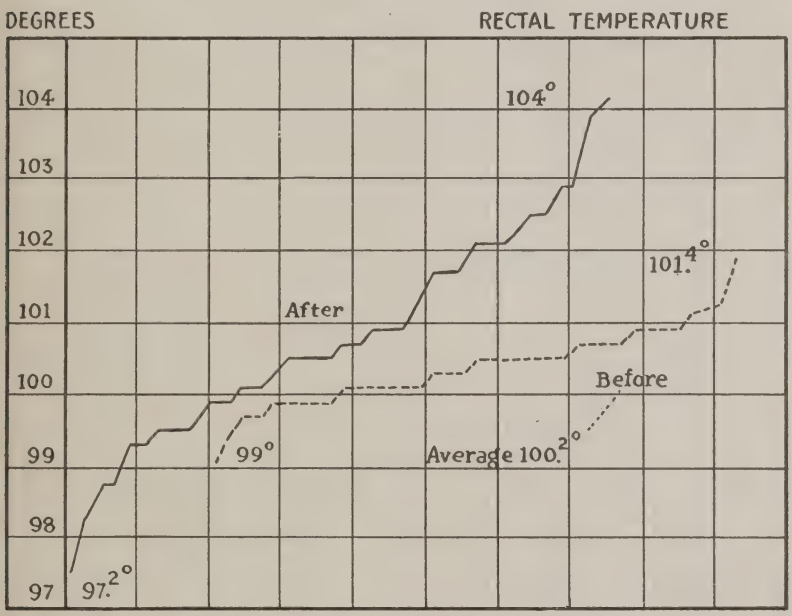
Mouth Temperature Before and After Race.

The comparison between the mouth temperature and the rectum proves conclusively that observations taken in the mouth after running are absolutely worthless. You will see by the chart that these observations showed an average falling off in temperature of 1⅕ degrees; whereas, it was fully expected and proved

by the rectal temperature that this condition should be reversed and there should be a decided rise.

Rectal Temperature.

There was an unexpectedly wide range in these temperatures, from 97⅖ degrees low to 104 degrees high. It is interesting to note that the man who finished with the highest temperature seemed to be in good condition at the finish, and said that he felt no distress after the seventeenth mile, and claimed to be a regular, and the only, drinker of liquor among the contestants; he had a systolic murmur at the finish which was not present at the start and he was the man who lost the second greatest amount of weight during the run.

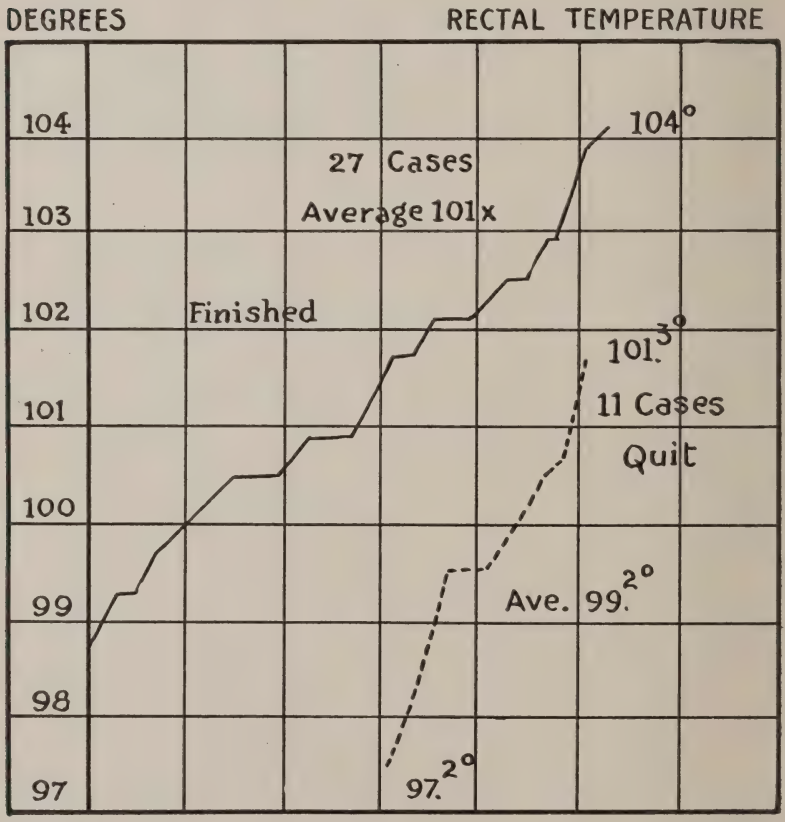


RECTAL TEMPERATURES BEFORE AND AFTER RACE.
Each horizontal square represents one man. Each vertical square represents 1° F.

The temperature of the winner was 102⅖ degrees at the finish. The variations of the temperature before the race were from 99 degrees to 101⅘ degrees. The one who had the highest temperature quit the race at eleven miles, and when examined his temperature had fallen 2 degrees, which was sub-normal. Before the race we found the average temperature in these cases to be

100⅖ degrees; what there was present to cause such a variation in temperature before the race is hard to tell, unless it be the varying element of nervous excitement; but there also seemed to be a corresponding variation in the temperature of the men after the race. We must, therefore, look to some other causes to account for the temperature range.

In undertaking to do this, we separated the quitters, those who did not complete the full distance, from those who were able to withstand the effort, as shown by their completing the distance, and a very interesting observation is made, as you will see by the chart. The average temperature of those who quit was 99⅖ degrees, while those who finished averaged at 101 degrees.



Upper Black Line shows Temperature of Men who Completed Race.
Lower Dotted Line shows Temperature of Men who Fell Out.

We must not forget that these men finished soon after the hard rain, which may have reduced their temperature, and they did not have sufficient time to recover from it, but still, I am not disposed to accept this as sufficient to account for the marked fall in temperature; I am rather disposed to think that the fall of temperature was a registration associated with some physiological condition which caused the men to quit. Of those who finished the average temperature was 101 degrees, ranging from 98⅗ degrees to 104 degrees.

The men whose records throughout the entire series of tests seemed to be perfect, likewise finishing the race with very little variation in temperature, leads one to think that there is a condition possible for a man to attain that will enable him to participate in this game without undue disturbance in his functions.

As will be seen from the X-Ray observation, the diaphragm assumes a much greater importance in the training of athletes for long distance running than has ever before been credited; it seemed the first organ to fatigue and cause distress. It is possible also that the lower temperatures of those who did not finish may be due to insufficient oxygenation, due to failure of the diaphragm. The hitherto unexplained pain commonly known as "stitch in the side," is, I believe, located in the diaphragm; the probable cause being cramp of the muscle due to the sudden severe demand made upon this organ and the effort to meet the demand.

General Conclusions.

From the general deductions of these observations and from my study of those of the succeeding papers, it appears that the athlete most likely to withstand this form of severe exertion is one not under twenty and not over forty years of age. It is likely that he will be of less than average height and underweight even for his height. He will have a light upper body, a relatively large chest capacity and well-developed legs. He must have a sound heart, healthy lungs and a well-developed diaphragm; all of which have properly accommodated to the increasing demands during the period of training. His training should have continued over a period of from nine months to three years.

During his training he must be temperate in his habits, avoiding stimulants of all kinds, moderate in his diet, avoiding extremes. He should work and exercise and sleep at regular hours, and of sleep he must have enough. The observations show clearly that the greatest injury comes to the man who is insufficiently trained, and that the successful running of this race is really beyond the realm of the average *amateur* athlete.

X-RAY EXAMINATIONS.

JNO. W. BOYCE, M. D., AND GEORGE W. GRIER, M. D.; ASSISTANTS,
D. E. SABLE, M. D., J. H. ALEXANDER, M. D.

The X-Ray examinations were made in the fluoroscopic laboratory of the West Penn Hospital by Dr. Jno. W. Boyce and myself with the above-named assistants.

Time of X-Ray Examinations.

The examinations before the race were made on the preceding evening. Those after the race were made shortly after the time of finishing or as they dropped out. The only intervening time was that spent in making the blood pressure and cardiac observations and the few minutes in the automobile to the hospital laboratory.

Technique of the X-Ray Examination.

The technique of each examination was exactly the same, so that the results of the several examinations on one man or of different men are comparable to each other.

During these examinations the same tube was used in exactly the same position. The tube and its holder were fastened upon a board which could be moved up and down in a frame, as a window sash in a casement; no other movement of the tube was possible. Eighteen inches in front of the board which carried the tube was placed a canvas screen, seven feet long and two feet wide. This canvas was about twenty-three inches from the source of origin of the rays on the anode of the tube.

This distance was constant, the canvas screen being fixed and the tube moving only in an up and down direction parallel to the face of the canvas, so that each man's back as he stood with his nude body just touching the screen was at exactly the same distance from the focus point on the tube. The tube was moved up or down until the anode was exactly level with the ensiform cartilage of the chest.

As it is absolutely essential for accurate fluoroscope work to have a perfectly dark room and for the investigator to stay in this room for some time before an examination begins so that his pupils will be properly dilated, it was impossible for the man making the tracings to leave the room until all men had been examined. All the tracings were made by Dr. G. W. Grier.

The work of setting the tube and placing the patient was done by Dr. Sable, it being of course necessary to turn on the light in the room while this was being done. During the time the light was turned on, the examiner stood with closed eyes so that when the room was again darkened, his eyes were in condition to go on immediately with the next examination.

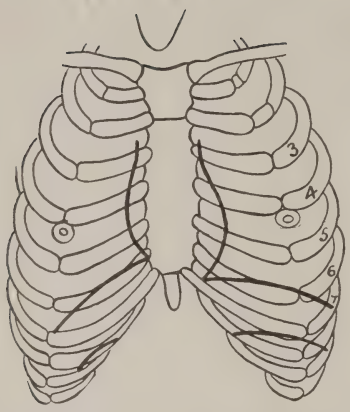
Tracings of the man's heart and of his diaphragm at rest and on deep inspiration were marked on his chest in blue pencil. This was done in the perfectly dark room as the man stood before the fluoroscopic screen. The permanent record was copied by an assistant, Dr. Sable, in an outer room.

Twenty-three men reported for the first examination, fourteen returned immediately after the race and eleven returned in one week for the final examination.

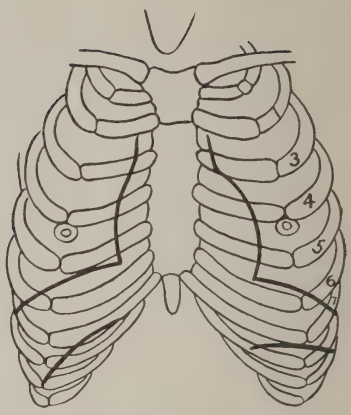
Size of the Hearts.

In comparing the hearts of these men the first and most obvious conclusion seemed to be their relative size. It is very difficult to say what the proper size for the heart of a certain individual should be, and whether at all there is such a thing as a proper sized heart, as the size of the heart seems to be an effect of environment. We have endeavored, therefore, to make an anatomical classification rather than a physiological one. In doing this, we divided these hearts as to size, in four classes: small, medium, large and very large. Of the small hearts Figure 1 is a fair example; of the medium, Figure 2; of the large, Figure 3; and of the very large, Figure 4. Those that were classified as small hearts we are sure would be called unusually small, and the very larges ones, unusually large, by the average clinician. In fact, those classed as large hearts are, in my opinion, abnormally large and would surely be classed as pathological for a man of sedentary occupation. Of 6 men with small hearts, none finished; of 8 men with medium hearts, 4 finished; of 7 men with large hearts, 4 finished; and of 2 men with very large hearts, 2 finished.

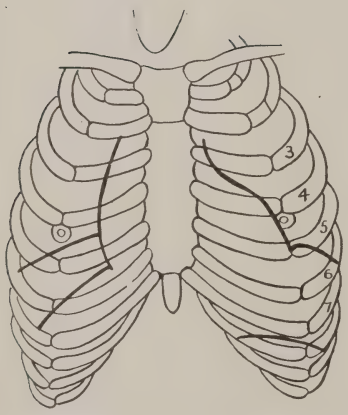
It is thus seen that of 9 men with hearts above the average size, 6 finished, 66⅔ per cent and that of 14 men whose hearts were not enlarged, only 4 finished, 28½ per cent. The conclusion to be drawn from this fact is obvious; that a successful Marathon runner must have a heart above the average size.



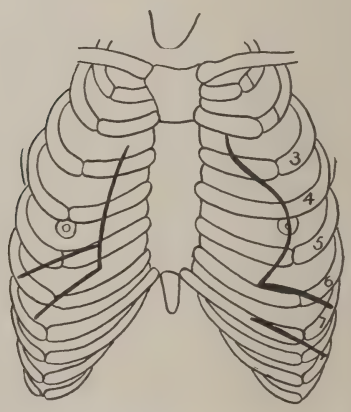
EXAMPLE OF SMALL VERTICAL HEART.
FIGURE I.



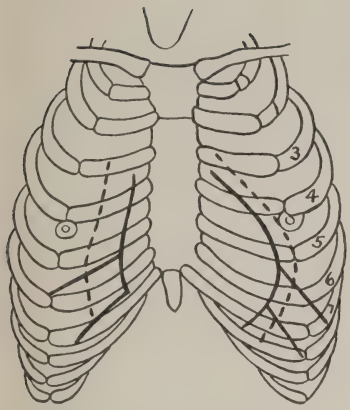
EXAMPLE OF MEDIUM SIZED HEART.
FIGURE II.



EXAMPLE OF LARGE HORIZONTAL HEART.
FIGURE III.

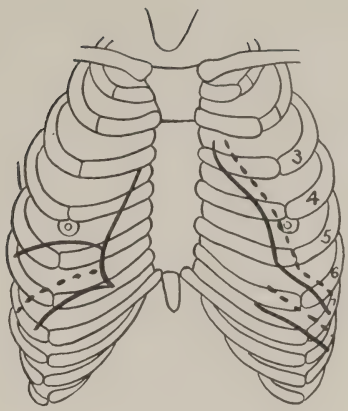


EXAMPLE OF VERY LARGE HEART.
FIGURE IV.



Dotted Lines Show Enlargement of Heart After Race.

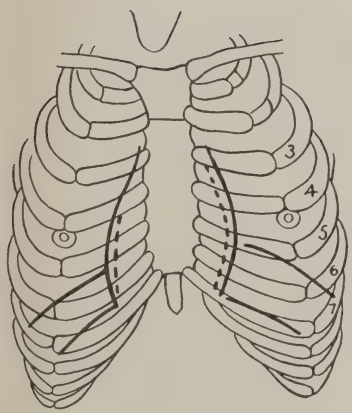
Figure V.



Showing One-sided Enlargement of Heart, also Typical Changes in Diaphragm After Race.

Dotted lines, after race.

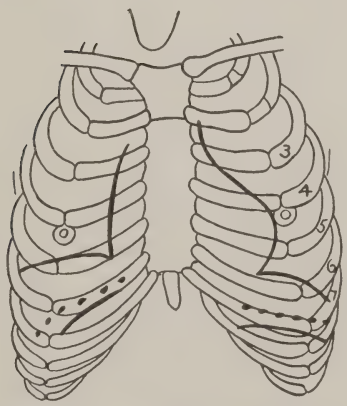
Figure VI.



Showing Typical Reduction in Size of Heart One Week After Race.

Dotted lines, after race.

Figure VII.



Only Case Finishing with No Enlargement of Heart.

Figure VIII.

Shape of the Heart Before Race.

In regard to the shape of the hearts of these different men, it is very difficult to make satisfactory classifications, as no two hearts of the 23 examined are of exactly the same shape. However, there were a sufficient number that followed two general shapes closely enough so that I think it may be of some value to note the results of these two groups. Eight of these 23 men had hearts which were placed almost vertically in the chest. Six of these 8 also had a heart below what might be considered as normal in size. In short, they had the small vertical heart often mentioned as being found in tubercular or tubercularly predisposed subjects. Of these 8 men with vertical hearts, none finished; 100 per cent failure. Figure 1 is a fair example of the vertical heart.

Six men presented the opposite extreme to a vertical heart, that is, a heart placed horizontally in the chest. Figure 3 is a fair example of this type of heart. Of these 6 men 5 finished, 83⅓ per cent, the only man with this shaped heart not finishing being an old man 52 years of age. Of the 9 remaining whose hearts we examined there is no general shape to which these hearts could be said to conform.

Figure 2 will serve, however, to show the contrast between these and the two preceding classifications. Of these 9 men 5 finished, 55½ per cent.

These findings then serve to confirm the conclusions made as to the proper size for an athletic heart which is in all cases an unusually large heart and particularly a heart of large ventricles. The lack of reserve force of the men of the small vertical heart, we believe, has been substantiated by those investigators who have shown this type of heart to be an important predisposition to, or a concomitant of, pulmonary tuberculosis.

In the X-Ray examination of a large number of tubercular subjects we have become firmly convinced of this fact and the failure of these men to finish the race seems an additional proof that a man with the small vertical heart should not attempt such violent exercise as a Marathon race.

Shape of Heart After Race.

Of the 14 men who presented themselves immediately after the race for examination, only 3 men had no enlargement of the heart over its size immediately before the race. Of these 3 men, 2 ran but 11 miles, and I think should not be further considered as they did not run far enough to be compared with the men that finished. The only man who did finish with no extra enlargement of the heart was No. 24, the tracing of whose heart is shown in Figure 8. This man's heart seems to us ideal in shape and size for an

athletic heart. He has been engaged in running for nine years, and is a well-trained athlete. His general condition at finish was excellent.

The enlargement of the heart during the race in the majority of cases was symmetrical, as shown in Figure 5. Of the 14 men who returned after the race 9 showed an enlargement of all chambers of the heart, 1 showed an enlargement of the right heart only, and 1 showed an enlargement of the left heart only. Three men had no change in the size of the heart. These 3 have already been discussed.

One Week After the Race.

One week after the race, 11 men presented themselves for examination and of these men, 2 still showed a heart of the same size as immediately after the race. Of these 2 men, one was the man 52 years of age who has been spoken of before as being too old to undertake such violent exercise. The other man showing a permanent enlargement of the heart following the race had a small, vertical heart which may have been in the process of acquiring the compensatory enlargement evidently necessary to all athletic hearts. The remaining 9 of the 11 men that presented themselves one week after the race had hearts smaller than they were before the race. This fact shows that these men in training for the race developed a temporary enlargement of the heart to provide for the additional work placed upon it during the race, and after the abnormal demands upon it ceased, the heart returned to its normal size.

Observations Upon the Diaphragm.

The changes of the diaphragm after the race were probably more striking even than those of the heart. Not only was there a decided change in the position and range of motion of the diaphragm after the race but there was also a decided difference in the two sides. On the right side in two cases the diaphragm occupied a higher position in the chest after the race, that is, it was not only higher in the chest while at rest, but also on deep inspiration its position was higher in the chest than during the corresponding phase of respiration before the race. In these two cases, the range of motion between the diaphragm at rest and on deep inspiration was less than before the race.

In 6 cases on the right side the position of the diaphragm at rest was the same as before the race, but it did not descend so far upon deep inspiration, the range of motion being obviously less than before the race. In these 8 cases, therefore, the range of motion was less than before the race. In 3 cases the position

and range of motion was the same on the right side as it was before the race. On the left side the condition of affairs was practically reversed, in 8 cases the diaphragm being higher in the chest than it was before the race both at rest and on full inspiration. However, there was not such a difference in the range of motion on the left side, and only 4 of the 8 cases had less range of motion than before the race, 2 having the same, and 2 having even a greater range of motion than before the race. In 2 cases on the left side the position was the same at rest as before the race, the diaphragm not descending so far in the chest on the full inspiration line.

Of the 11 cases, therefore, on the left side, 6 had a less range of motion, 2 had the same and 3 had more than before the race. In these cases, I should say that the tendency seems to be after prolonged violent exercise for the diaphragm to occupy a higher position in the chest and to have a decidedly less range of motion than before, as shown in Figure 6. Three of these cases presented an anomalous condition, which to my knowledge, has never been described before. In these cases the diaphragm on both sides did not descend on full inspiration and on urging the man to further efforts of inspiration, actually ascended into the chest, in one case flattening out at the same time. This action was undoubtedly due to the fatigue of the diaphragm, but why that complex and always very interesting organ should present this particular phenomenon, and the method of its production, I have so far been unable to determine.

Table Showing Per Cent Who Finished with Reference to Size of Heart.

Small	Medium	Large	Very Large
0 per cent	50 per cent	57 per cent	100 per cent
28½ per cent		66⅔ per cent	

PHYSIOLOGICAL AND PATHOLOGICAL EFFECTS ON THE CIRCULATORY AND RENAL SYSTEMS.†

JOSEPH H. BARACH, M. D., ASSISTED BY DR. C. L. PALMER, DR. F. D. STOLZENBACH, DR. H. G. WERTHEIMER.

The extreme importance of the rôle played by the circulatory system in severe and prolonged exertion need hardly be emphasized here. It may be said, in fact, that the circulatory system bears the brunt of the effort, and its condition, therefore, determines to a very great degree the success or failure of the contestant. The following observations upon fifty-five contestants were made in the order which they are here presented:

Pulse Rate During Training.

At some time during the week before the run we had the contestants count their pulse in the morning before getting out of bed and in the evening before retiring. They all ran their training distance on that day, which varied from 2 to 18 miles, the average being 7.

Table 1 shows the morning pulse to have been below 71 in 13 out of 16 cases, and the evening pulse was below 71 in 10 out of 16 cases. Taken as a whole, the pulse rate is a little slower than what is considered normal for the average individual.

Table 1. Morning and Evening Pulse During Training

Morning Pulse.	Cases.	Evening Pulse.	Cases.
40-50	1	40-50	0
50-60	6	50-60	2
60-70	6	60-70	8
70-80	3	70-80	6
	16		16

Relation of Morning and Evening Pulse.

I noticed that in about half of the number there was a marked difference between the morning and evening pulse rate. In Table 2 these cases are separated in two groups. A further study brought out the interesting fact that those subjects who showed

†Presented by invitation before the American Physiological Society at the Harvard Medical School December 30, 1909, Boston.

the greater diurnal variation had higher blood pressures. And there was but one subject that showed high blood pressure who did not have this marked diurnal variation.

The subjects in the second group are further advanced in life than those of the first group and a higher blood pressure is to be expected; nevertheless, as will be seen later, these readings are higher than they should be, all things considered.

TABLE 2. MORNING AND EVENING PULSE DURING TRAINING.

NORMAL VARIATION.				HYPERNORMAL VARIATION.			
	—Pulse—				—Pulse—		
Age.	A.M.	P.M.	B.-P.	Age.	A.M.	P.M.	B.-P.
18	72	68	110	20	52	53	140*
19	58	58	118	21	60	74	135
19	54	64	120	25	50	70	150
22	60	65	125	29	60	74	162
22	70	74	125	31	48	67	138
29	64	66	115	36	55	65	132
29	60	62	122	36	70	78	140
29	65	71	120	52	56	68	134

* Exceptional case.

PULSE RATE BEFORE THE RACE.

The pulse rate was taken in the horizontal position in all cases before the race, half of them on the preceding evening and the others in the forenoon within three hours before the race. So far as could be estimated, the psychic influence of our investigations on these contestants at this time was not a considerable factor, as we made an effort to put them at ease so as to eliminate, if possible, such influence on the pulse-rate and blood-pressure readings. Table 3 shows that, while the pulse varied from 50 to 110, in most cases it was normal.

TABLE 3. PULSE RATE BEFORE RACE.

No. Cases.	Pulse Rate.	No. Cases.	Pulse Rate.
2	50–55	10	80– 85†
0	55–60*	1	85– 90
7	60–65*	2	90– 95
11	65–70*	2	95–100
9	70–75*	1	100–105
8	75–80†	2	105–110

Total number of cases, 55.

* Pulse rate 55 to 75, 27 cases. † Pulse rate 75 to 85, 18 cases.

BLOOD PRESSURE STUDIES.

These records were made with the Erlanger and the Stanton sphygmomanometers. They were both fitted with the same width rubber cuff (10 cm.) and had been previously tested and compared. All the work referred to in this paper was performed with the instruments used in these observations.

Before the race we obtained complete records made with the Erlanger instrument in 24 cases and with the Stanton in 21. No attempt was made at reading the diastolic pressure with the Stanton instrument.

Normal Blood Pressure.

As a basis for comparison in this series a curve was constructed based on 90 blood-pressure observations in normal males at the succeeding years. This is shown in Chart 1 and the succeeding charts of averages. Of the individuals of 60 and over, while it may be said that they should not be considered normal on account of the changes that are invariably present at that age, yet I can affirm that they were distinctly free from marked evidences of disease.

It will be noted that with the advance of years the curve gradually tends upward. This seems in accordance with the fact that the heart enlarges as the age of the individual progresses.

With this line as a normal level of the maximum blood pressure, in all of my observations in the past, I have found that a variation of more than 25 mm. above or below is usually associated with evidence of disease.

Maximum Blood Pressure Before Race.

These determinations were made with the Erlanger instrument eighteen hours before the race in 24 cases, and with the Stanton two hours before the race in the other 29 of the series. The average maximum blood pressure of the entire series of 53 cases was 126.5 mm.

The average maximum of these cases, arranged according to the age, is shown in Table 4, which shows the constancy and regularity with which the blood pressure rises as age advances.

Table 4. Average Maximum Blood Pressure Before Race in 45 Cases.

No. Cases.	Age.	Average Maximum B.-P.
12	18-20	122.75
20	20-25	125.05
11	25-30	129.00
2	30-35	136.00

The average maximum, minimum and pulse pressures of these contestants, first in the horizontal and then in the erect position of the body, is to be seen in Table 5. These cases are arranged in the order in which the contestants finished in the race. As is well known, the change of the body posture causes certain alterations in the relation of the pulse and blood pressures. These are noted in the last column of the table as plus, minus and equal. The conclusions from these will be commented on later.

Table 5. Blood Pressures Before the Race in Horizontal and Erect Postures.

	Horizontal					Erect				Result.		
			B.-P.			B.-P.						
No.	Age.	Pulse.	S.	D.	P.-P.	Pulse.	S.	D.	P.-P.	P.	S.	D.	P.-P.
4	18	72	110	90	20	72	115	80	35	=	+	−	−
5	28	105	132	98	34	97	128	95	33	−	−	−	−
7	36	63	132	100	32	76	132	100	32	+	=	=	=
11	19	78	120	85	35	90	120	80	40	+	=	−	+
12	21	76	145	100	45	80	145	100	45	+	=	=	=
13	22	74	125	100	25	76	122	100	22	+	−	=	−
15	19	84	110	90	20	84	118	85	33	=	+	−	+
17	23	106	135	90	45	106	135	100	35	=	=	+	−
19	27	66	122	90	32	76	118	90	28	+	−	=	−
22	21	80	130	100	30	83	132	110	22	+	+	+	−
24	27	67	120	95	25	72	130	100	30	+	+	+	+
27	19	54	118	92	26	74	112	92	20	+	−	=	−
30	25	65	110	90	20	70	112	98	14	−	+	+	−
32	52	82	134	100	34	78	138	100	38	−	+	=	+
38	21	69	124	95	29	76	120	100	20	+	−	+	−
39	19	87	155	130	25	84	142	118	24	−	−	−	−
40	23	66	133	110	23	66	135	100	35	=	+	−	+
41	?	64	130	92	38	64	132	90	42	=	+	−	+
43	20	75	120	88	32	76	100	80	20	+	−	−	−
47	29	83	162	112	50	85	150	105	45	+	−	−	−
48	27	62	130	100	30	72	120	100	20	+	−	=	−
49	27	72	130	95	35	70	132	100	32	−	+	+	−
50	21	70	105	85	20	70	110	85	25	=	+	=	+
51	18	76	118	95	23	83	110	95	15	+	−	=	−
										+14	+10	+ 8	+ 8
										− 4	−11	− 9	−14
Average		74.8	127.8	96.7	30.3	78.3	124.9	95.9	29.3	= 6	= 3	= 9	= 2

Table 6. Maximum, Minimum and Pulse Pressure Before Race According to Age.

Horizontal.

—Age 18 to 20—			—Age 20 to 25—			—Age 25 to 30—			—Age 35 to 40—		
Max.	Min.	P.-P.	Max.	Min.	P.-P.	Max.	Min.	P.-P.	Max.	Min.	P.-P.
110	90	20	145	100	45	132	98	34	132	100	32
120	85	35	125	100	25	122	90	32	...	...	..
110	90	20	135	90	45	120	95	25	...	...	..
118	92	26	130	100	30	110	90	20	...	...	..
155	130	25	124	95	29	162	112	50	...	...	..
118	95	23	133	110	23	130	100	30	...	...	..
...	...	..	120	88	32	130	95	35		AGE 52	
...	...	..	105	85	20	...	...	..	134	100	34
Average:											
121.8	97.	24.8	123.3	96.	31.	129.	98.	32.			

Erect.

115	80	35	145	100	45	128	95	33	132	100	32
120	80	40	122	100	22	118	90	28	...	...	..
118	85	33	135	100	35	130	100	30	...	...	..
112	92	20	132	100	22	112	98	14	...	...	..
...	...	..	120	100	20	150	105	45	...	...	..
142	118	24	...	..	..	...	...	..	...	...	..
...	...	..	135	100	35	120	100	20	...	...	..
110	95	15	...	...	..	...	...	..	...	...	..
...	...	..	100	80	20	132	100	32		AGE 52	
...	...	..	110	85	25	...	...	..	138	100	38
Average:											
119.5	91.6	27.8	124.8	95.6	28.	127.	98.2	28.8			

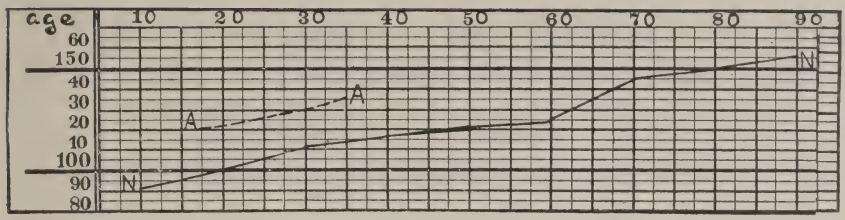


Fig. 1.—Average maximum blood pressure (before the race) of contestants (line A-A) compared with average maximum blood pressure in 90 normal men (line N-N).

On the maximum blood pressures in all the subjects at their respective ages I have constructed the chart shown in Figure 1, and it is to be noted that this curve is at about the upper limit of the normal blood-pressure zone.

Relation of Body Weight to Blood Pressure.

Table 7 shows that half of the overweighted subjects and a little over a third of the underweighted subjects had higher than average blood pressure. Between the degree of overweight and the height of the blood pressure there was no relation whatever.

Table 7. Relation of Body Weight to Blood-Pressure.

53 Cases.

	Cases.	Hypertension.
Underweight	34	10
Overweight	16	8
Normal	3	0

Relation of Occupation to Blood Pressure.

The occupations were subdivided according to the amount of physical strain. Only those were classified with the hypertension cases whose pressures were distinctly above the average for the age of the subjects.

Table 8. Relation of Occupation to Blood Pressure.

	B.-P. Average.	B.-P. Above Average.
Professional	2	1
Clerk	7	1
Light Labor	6	2
Total	15	4
Heavy Labor	9	13

Relation of Previous Marathon Runs to Blood Pressure.

Some of the contestants were experienced long-distance runners, but most of them had partaken in long-distance races not more than one year; so that the extra strain thrown on the circulatory system was rather sudden and in some instances was persistent during the entire year or less.

Table 9 shows the number of races run and the time of long-distance running. The runners showing high blood pressure are in those who had trained for and run from three to five races within the first year of their experience. The experienced runners of nine, ten, eleven and twenty years all had average blood pressures.

Table 9. Previous Runs and Blood Pressure.

Years Long Dis. Run.	Marathon Races.	Blood Pressure.
20	8	Average
11	3	Average
10	3	Average
9	4	Average
2	5	Average
1	5	High
1	5	High
1	4	High
1	4	Average
1	3	High
1	3	High
1	3	Average
1	3	Average
1	3	Average
1	2	Average

Heart Cases.

Auscultation was carried out in every one of the 55 contestants, within twenty-four hours before the race, with abnormal findings in seven cases, as shown in Table 10.

Table 10. Heart Cases.

	Cases.
Systolic murmur at apex	4
Systolic murmur at pulmonic area	1
Muffled first sound at apex	1
Arrhythmia	1

On inspection, a considerable number showed very prominent apex beat, and in nearly all cases the impulse was plainly visible. Percussion was not carried out, as the presence of hypertrophy was to be determined by a more accurate method.

Blood Pressure in Heart-Murmur Cases.

In each of the five murmur cases there was a maximum and minimum pressure distinctly above the normal line, and four of them showed a pressure very much higher than the average height.

Table 11 gives the readings in these cases, and Figure 2 shows their maximum blood pressure as compared with the other athletes and normal individuals.

TABLE 11. HEART-MURMUR CASES.

Age.	Max. Blood Pressure.	Min. Blood Pressure.
18	110	90
19	155	130
21	140	100
29	162	112
36	132	110

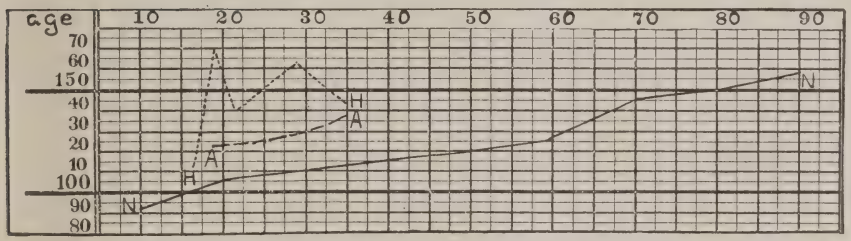


Fig. 2.—Average maximum blood pressure (line H-H) of five contestants with heart murmurs (before the race) compared with average maximum blood pressure of other contestants (line A-A) and of normal men (line N-N).

RELATION OF HEART CASES TO BODY WEIGHT.

Having learned that in these cases there was no history of cardiac involvement from disease, I thought it might be of interest to search for other causative factors. We have studied the age, height and weight of these contestants and classified them as over, under and normal weight. The relation of these heart cases to the body weight is shown in Table 12.

TABLE 12. BODY WEIGHT IN HEART CASES.

BEFORE RACE.		AFTER RACE.	
Heart.	Weight.*	Heart.	Weight.
Intermittent.....	–	Intermittent.....	–
Syst. Apex.....	N	Syst. Base.....	–
Syst. Apex.....	–	Syst. Apex.....	N
Syst. Apex.....	–	Syst. Apex.....	–
Syst. Apex.....	+	Irreg.....	–
Syst. Pulmonic	+		
Arrhythmia	–		

* In this column + means overweight; –, underweight, and N, normal.

The table shows that the murmurs were entirely independent of body overweight, and that the proportion of underweight cases is about the same as in the entire series.

Blood Pressure After the Race.

The blood-pressure readings were made immediately after the finish in nearly every case. In only a few instances was it delayed four or five minutes after entrance to the medical tent. For comparison, the readings obtained before the race are repeated in the following tables. The average of the maximum pressures before the race was 126.5 (53 cases) and 107.3 (38 cases) after the race.

Table 13 gives the readings in the individual cases after the race and the average pulse rate, maximum, minimum and pulse pressures, in the horizontal and erect postures. The effects resulting from the change of posture are to be noted in the last column.

Table 13. Pulse Rate and Blood Pressure in Horizontal and Erect Postures After the Race.

		Horizontal				Erect				Result.			
			B.-P.				B.-P.						
No.	Age.	Pulse.	S.	D.	P.-P.	Pulse.	S.	D.	P.-P.	P.	S.	D.	P.-P.
4	18	93	95	88	7	112	98	90	8	+	+	+	+
5	28	120	95	80	15	138	90	?	?	+	−	..	..
7	36	112	88	?	..	120	88	?	..	+	=	..	..
11	19	112	100	70	30	112	108	75	33	=	+	+	+
12	21	100	108	80	28	108	100	80	20	+	−	=	−
13	22	96	94	74	20	100	92	80	12	+	−	+	−
15	18	104	105	80	25	120	110	75	35	+	+	−	+
17	23	106	100	80	20	116	88	75	13	+	−	−	−
19	27	93	110	85	25	114	100	85	15	+	−	=	−
22	21	90	100	82	18	96	85	70	15	+	−	−	−
24	27	80	110	72	38	93	105	80	25	+	−	+	−
27	19	80	114	90	24	116	108	90	18	+	−	=	−
30	25	81	110	95	15	96	110	92	18	+	=	−	+
32	52	106	118	92	26	129	108	90	18	+	−	−	−
38	21	81	80	75	5	99	95	80	15	+	+	+	+
39	19	108	92	78	14	120	82	72	10	+	−	−	−
40	23	114	108	88	20	135	108	88	20	+	=	=	=
41	?	60	122	88	34	81	130	100	30	+	+	+	−
43	20	92	120	88	32	110	100	80	20	+	−	−	−
										+19	+ 5	+ 6	+ 5
										= 1	−12	− 8	−12
Average		95.6	103.6	82.5	22.	111.3	100.2	82.4	19.1	− 3	= 3	= 4	= 1

The averages of the readings after the race (Table 13), as compared with the findings previous to the race, are shown in Table 14.

Table 14. Pulse Rate, Maximum, Minimum and Pulse Pressure, Before and After the Race.

		Horizontal				Erect			
	Cases.	Pulse.	Max.	Min.	P.-P.	Pulse.	Max.	Min.	P.-P.
Before.....	24	74.8	127.8	96.7	30.3	78 3	124.0	95.9	29.3
After.....	19	95.6	103.6	82 5	22.0	111.3	100.2	82.4	19.1

Arranged according to age, the individual readings are to be seen in Table 15.

TABLE 15. MAXIMUM, MINIMUM AND PULSE PRESSURE AFTER RACE, ACCORDING TO AGE OF SUBJECTS.

HORIZONTAL.

—Age 18 to 20—			—Age 20 to 25—			—Age 25 to 30—			—Age 35 to 40—		
Max.	Min.	P.-P.	Max.	Min.	P.-P.	Max.	Min.	P.-P.	Max.	Min.	P.-P.
95	88	7	108	80	28	95	80	15	88	?	?
100	70	30	94	74	20	110	85	25	...	..	..
105	80	25	100	80	20	110	72	38	...	..	..
114	90	24	100	82	18	110	95	15	...	..	..
...	..	..	80	75	5	...	..	..	...	..	..
92	78	14	...	..	..	...	..	..	...	..	..
...	..	..	108	88	20	...	..	..		AGE 52	
...	..	..	120	88	32	...	..	..	118	92	26
Average:											
101.2	81.2	20.	101.4	81.	20.4	106.2	83.	23.2			

ERECT.

98	90	8	100	80	20	90	?	?	88	?	?
108	75	33	92	80	12	100	85	15	...	..	..
110	75	35	...	..	..	...	..	..	...	..	..
...	..	..	85	70	15	110	92	18	...	..	..
108	90	18	...	..	..	...	..	..	...	..	..
...	..	..	95	80	15	...	..	..	...	..	..
82	70	10	...	..	..	...	..	..	...	..	..
...	..	..	108	88	20	...	..	..		AGE 52	
...	..	..	100	80	20	...	..	..	108	90	18
Average:											
101.2	80.4	20.8	95.4	79.	16.4	101.1	85.6	19.3			

The chart shown in Figure 3 is based on the readings obtained immediately after the race. It shows the normal curve, the curve based on the average of all the cases after the race, and the blood-pressure readings in the murmur cases. It will be noted that the total average curve is now below the normal line, whereas before the race it was about 25 mm. above the line. It will also be noted that the murmur cases suffered a greater fall than the others.

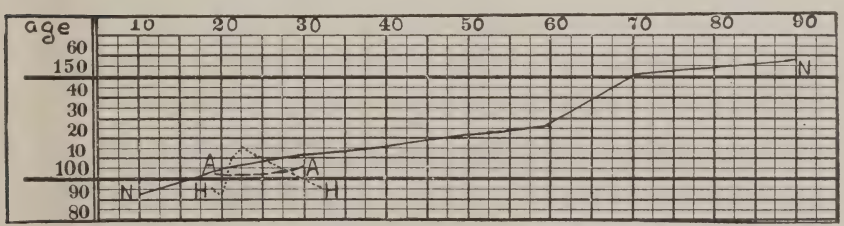


Fig. 3.—Average maximum blood pressure after the race in the contestants with heart murmurs (line H-H) and in all contestants (line A-A) compared with normal curve (line N-N).

Heart Cases in the Race.

Of the 5 runners who had murmurs before the race, 4 ran the full distance and one ran nineteen miles. Three of these were among the first 12 to finish the race. These runners were all new to long-distance running.

After the race the hearts were auscultated in the first 45 as they finished. Out of the 29 that finished within the time limit (four hours, fifteen minutes) 5 presented heart conditions. Table 16 shows the place in which they finished. The fourth column in Table 16 shows the proportion of the pulse pressure after the race to that before.

Table 16. Pulse Pressure Before and After the Race in Runners with Heart Symptoms.

Finished.	Before Race.	After Race	Pulse Pressure. After.	Before.
2d.....	Muffled apex first	Intermittent and weak	..	..
3d.....	O	Systolic base	..	..
4th.....	Systolic apex	Systolic apex	7:	20
5th.....	O	Systolic apex	15:	34
7th.....	Systolic apex	O	?:	32
12th.....	Systolic pulmonic	O	20:	45
29th.....	O	Irregular	..	..
39th.....	Systolic apex	O	10:	29
47th.....	Systolic apex	Not examined	..	..
50th.....	Arrhythmia	Not examined	..	..

These "heart subjects" had more rapid pulses and smaller pulse pressures as a result of the exertion. Their blood pressures are shown in the charts, Figures 2 and 3.

Blood Pressure Ten Days Subsequent to the Race.

At this time we find the blood pressure about the same as before the race, or, rather, it was nearer the normal line than before.

Table 17. Average Maximum Blood-Pressure Before, Immediately After, and Ten Days Subsequent to the Race.

		Cases.
Before	126.5	53
Immediately after	107.3	38
Ten days subsequent	124.7	19

Table 18 shows the average pulse rate, maximum and minimum, and pulse pressures in the horizontal and erect postures, as compared with the tables of the same data before and after.

TABLE 18. AVERAGE MAXIMUM, MINIMUM AND PULSE PRESSURES TEN DAYS SUBSEQUENT TO RACE.

		Horizontal				Erect			
	No. Cases.	Pulse.	Max.	Min.	P.-P.	Pulse	Max.	Min.	P.-P.
Before	24	74.8	127.8	96.7	30.3	78.3	124.0	95.9	29.3
Immediately after	19	95.6	103.6	82.5	22.0	111.3	100.2	82.4	19.1
Ten days subsequent	17	61.8	124.7	92.1	33.7	68.2	125.1	93.2	31.2

The readings in the individual cases are to be seen in Table 19, and these cases, arranged according to age of subjects, are given in Table 20.

TABLE 19. INDIVIDUAL MAXIMUMS, MINIMUMS AND PULSE PRESSURES TEN DAYS SUBSEQUENT TO RACE.

		SUBSEQUENT.											
		Horizontal				Erect							
		B. P.				B.-P.				Result.			
No.	Age.	Pulse.	S.	D.	P.-P.	Pulse	S.	D.	P.-P.	P.	S.	D.	P.-P.
4	18	50	125	88	37	52	130	95	35	+	+	+	−
5	28	76	119	90	29	80	120	90	30	+	+	=	+
7	36	64	124	87	37	70	118	100	18	+	−	+	−
11	19	62	120	85	35	80	130	100	30	+	+	+	−
12	21	68	152	100	52	74	152	100	52	+	=	=	=
13	22	63	110	75	35	66	110	80	30	+	=	+	−
15	18	52	120	95	25	70	122	92	30	+	+	−	+
17	23	73	118	80	38	90	120	90	30	+	+	+	−
19	27	48	130	100	30	52	138	98	40	+	+	−	+
22	21	72	138	90	48	90	128	98	30	+	−	+	−
24	27	78	120	90	30	76	120	90	30	=	=	=	=
27	19	66	135	88	47	54	120	92	28	−	−	+	−
30	25	56	112	92	20	58	112	92	20	+	=	=	=
32	52	56	144	110	34	64	155	110	45	+	+	=	+
38	21	56	110	88	22	52	110	78	32	−	=	−	+
40	23	62	125	100	25	66	132	100	32	+	+	=	+
43	20	56	118	88	30	66	110	90	20	+	−	+	−
										+14	+ 8	+ 8	+ 6
										− 2	− 4	− 3	− 8
Average:		61.8	124.7	92.1	33.7	68.2	125.1	93.2	31.2	= 1	= 5	= 6	= 3

TABLE 20. PRESSURE READINGS TEN DAYS SUBSEQUENT TO RACE, ARRANGED ACCORDING TO AGE OF SUBJECTS.

HORIZONTAL.

— Age 18 to 20 —			— Age 20 to 25 —			— Age 25 to 30 —			— Age 35 to 40 —		
Max.	Min.	P.-P.	Max.	Min.	P.-P.	Max.	Min.	P.-P.	Max.	Min.	P.-P.
125	88	37	152	100	52	119	90	29	124	87	37
120	85	35	110	75	35	130	100	30	...	...	..
100	95	25	118	80	38	120	90	30	...	...	..
135	88	47	138	90	48	112	92	20	...	...	..
...	...	..	110	88	22	...	...	..	...	...	..
...	...	..	125	100	25	...	...	..		AGE 52	
...	...	..	118	88	30	...	...	..	144	110	34
Average:											
120.	89.	36.	124.3	90.	35.	120.	93.	27.			

ERECT.

130	95	35	152	100	52	120	90	30	118	100	18
130	100	30	110	80	30	138	98	40	...	...	..
122	92	30	120	90	128	120	90	30	...	...	..
120	92	28	128	98	30	112	92	20	...	...	..
...	...	..	110	78	32	...	...	..	...	...	..
...	...	..	132	100	32	...	...	..		AGE 52	
...	...	..	110	90	20	...	...	..	155	110	45
Average:											
125.	72.	30.	123.	90.8	46.	122.	92.	30.			

Six months later we examined five of these runners and found the blood pressures lower than at the previous examination; their pressures were gradually lowering toward the normal average. The readings in these cases are seen in Table 21.

Table 21. Pressure Readings in Five Cases Six Months After Race.

Horizontal.

—Age 18 to 20—			—Age 20 to 25—			—Age 25 to 30—		
Max.	Min.	P.-P.	Max.	Min.	P.-P.	Max.	Min.	P.-P.
120	90	30	122	98	24	110	84	26
120	86	34	...	...	..	...	..	..
106	84	22	...	...	..	...	..	..
Average:								
115.	86.	28.	122.	98.	24.	110.	84.	26.

Erect.

110	86	24	130	100	30	110	82	28
110	85	25	...	...	..	...	..	..
112	90	22	...	...	..	...	..	..
Average:								
110.	87.	23.	130.	100.	30.	110.	82.	28.

The chart shown in Figure 4 is based on the findings at the examinations ten days and six months after the race. The curve at the final examination is nearer the normal level.

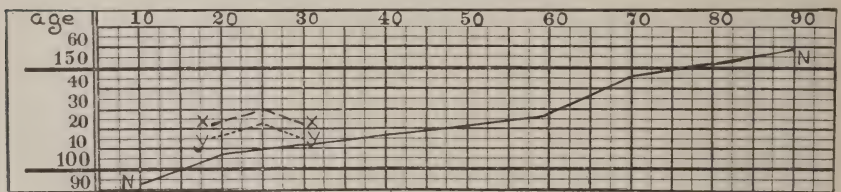


Fig. 4. — Average maximum blood pressures (all contestants) obtained ten days (line X-X) and six months (line Y-Y) after the race, compared with normal curve (line N-N).

Each of the four charts 5, 6, 7 and 8 represents the blood-pressure curve of an individual case. They all show the marked fall resulting from the exertion, the height of the blood pressure ten days after the race, and the extent to which it had fallen at the end of six months. In the case of M——e it will be noted that at the end of six months his blood pressure did not recede toward the normal level as the others; the reason for this is that he had kept up his training and long-distance running to the very day of the last examination. With the high pressure he still had the mitral systolic loud blowing murmur which he presented at all of the previous examinations.

In the last case, that of O——n, who had a murmur before and immediately after the race, it was found ten days later that the murmur could be brought out only by his pacing, and at the end of six months, even after pacing for a full half minute, it could not be heard. In this case, with the disappearance of the hypertrophy which was accompanied by a falling of the blood pressure, there was a simultaneous disappearance of the murmur.

Comparison of Blood Pressure Observations Before, Immediately After and Ten Days and Six Months Subsequent to the Race.

On the tables 1 to 21 I have constructed Charts 1 to 9. All considered, the conclusions from these evidences are that as a result of training for the Marathon race a state of increased blood pressure is developed, which is considerably above normal. In some cases when training is carried to a more severe degree or because of a preceding state of the heart, we find still higher blood pressures associated with heart murmurs.

As a result of the race the maximum, minimum and pulse pressures in all cases are lowered, reaching a point below the normal

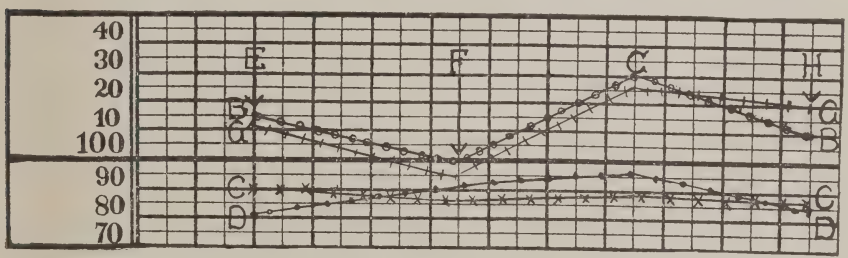


Fig. 5.—Blood pressures, case of H—n; line A-A, maximum horizontal; line B-B, maximum erect; line C-C, minimum horizontal; line D-D minimum erect; E, before race; F, immediately after; G, ten days, and H, six months subsequent to race.

average; and in the "heart" cases a greater fall is suffered than in the others.

Ten days subsequent to the race we find the blood pressure about the same as before the race, or, rather, it is nearer the normal line. Six months after the race we find the blood pressure lower than it was at the previous examination; i.e., still nearer to the normal.

Effect of Change of Posture on Blood Pressure.

The observations were made first in the horizontal and then in the erect posture. The surrounding conditions were as follows:

Being in June, the external temperature was warm. The contestants were stripped; they had been weighed, measured, hearts auscultated, all of which allowed them about ten minutes in the room previous to the blood-pressure examination. They then walked over to the table and lay down, after which the armlet was applied. Within three to five minutes the reading was made.

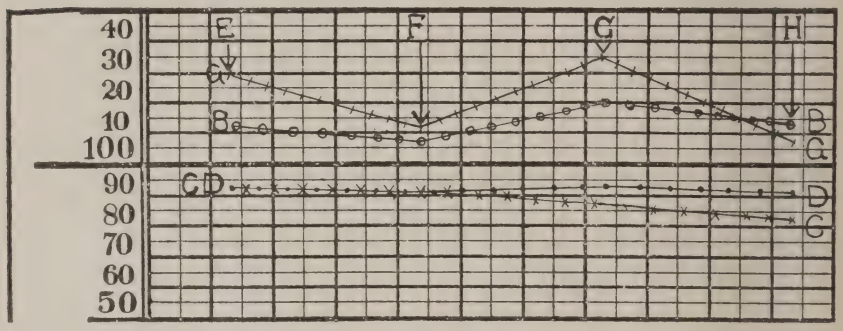


Fig. 6.—Blood pressures, case of M—e; maximum and minimum, horizontal and erect, and times of examination indicated as before. Mitral systolic murmur heard at each examination.

Without removing the cuff they were directed to get up and stand beside the table, not being allowed to lean against it, while the second reading was made. After the race they were laid on the table immediately on entering the medical tent (on a run). While

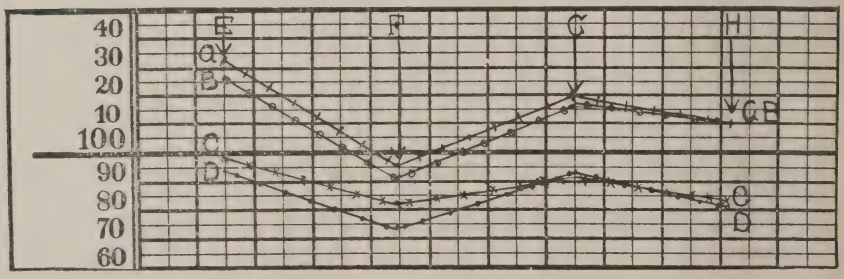


Fig. 7.—Blood pressures, case of H—s; maximum and minimum, horizontal and erect, and times of examination indicated as before.

I was making the blood-pressure observation another man counted the pulse. When this was done, the contestant was directed to get up, in many instances having to be assisted; to stand as erect as possible without leaning against the table while the second

reading was being made. The technic of the subsequent examinations was the same as that of the first. This change from the horizontal to the erect posture caused alterations in the blood pressure which may be seen in the last columns of Table 5, 14 and 19. These effects are summarized in Table 22.

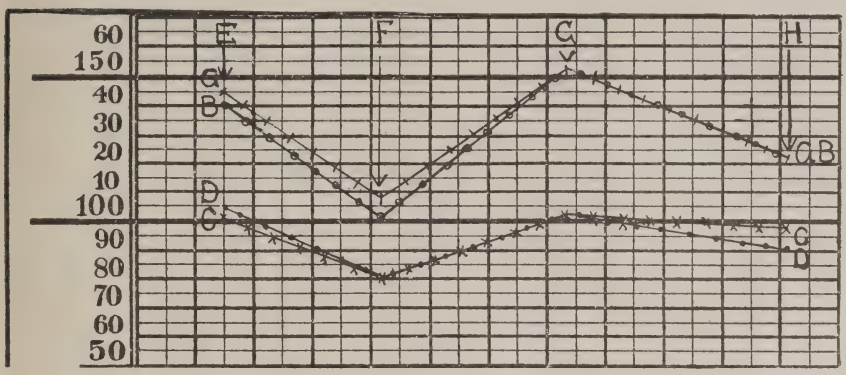


Fig. 8.—Blood pressures, case of O—n; maximum and minimum, horizontal and erect, indicated as before. Pulmonary systolic murmur heard before, after, and at the third examination, but at the time of the fourth examination it had disappeared.

TABLE 22. EFFECT OF CHANGE OF POSTURE ON BLOOD PRESSURE.

	Increased. No. Cases.	Diminished. No. Cases.	Unchanged. No. Cases.
BEFORE RACE			
Pulse	14	4	6
Maximum	10	11	3
Minimum	6	9	9
Pulse pressure	8	14	2
IMMEDIATELY AFTER RACE.			
Pulse	19	..	1
Maximum	5	12	3
Minimum	6	8	4
Pulse pressure	5	12	1
TEN DAYS SUBSEQUENT TO RACE.			
Pulse	14	2	1
Maximum	8	4	5
Minimum	8	3	6
Pulse pressure	6	8	3

CONCLUSIONS IN REGARD TO EFFECT FROM CHANGES OF POSTURE.

Before Race.

From these observations we may then say that in individuals with sound hearts having a definite degree of hypertrophy, as a result of change in posture, from the horizontal to the erect, there

is a rise in pulse rate, the maximum pressure may be increased or diminished, the minimum pressure may be diminished or equal, and with this there will be a diminution of pulse pressure. This occurs in more than half of the cases.

Immediately After Race.

Following severe muscular exertion, in the greater number of cases, the change from the horizontal to the erect posture caused an increase in pulse rate, a falling of maximum and minimum pressure, and with this a lowering of pulse pressure.

Ten Days and Six Months Subsequent to the Race.

The changes were the same as before the race.

Effect of Change of Posture in Heart Cases.

So far as could be seen these cases did not show a more striking uniformity in reaction to the change of posture than the other cases.

Relations of Maximum, Minimum and Pulse Pressures to Each Other.

In most of these records it will be seen that the height of the minimum pressure was in proportion to the maximum, and that the pulse pressure was greatest in those cases showing the highest maximum pressures.

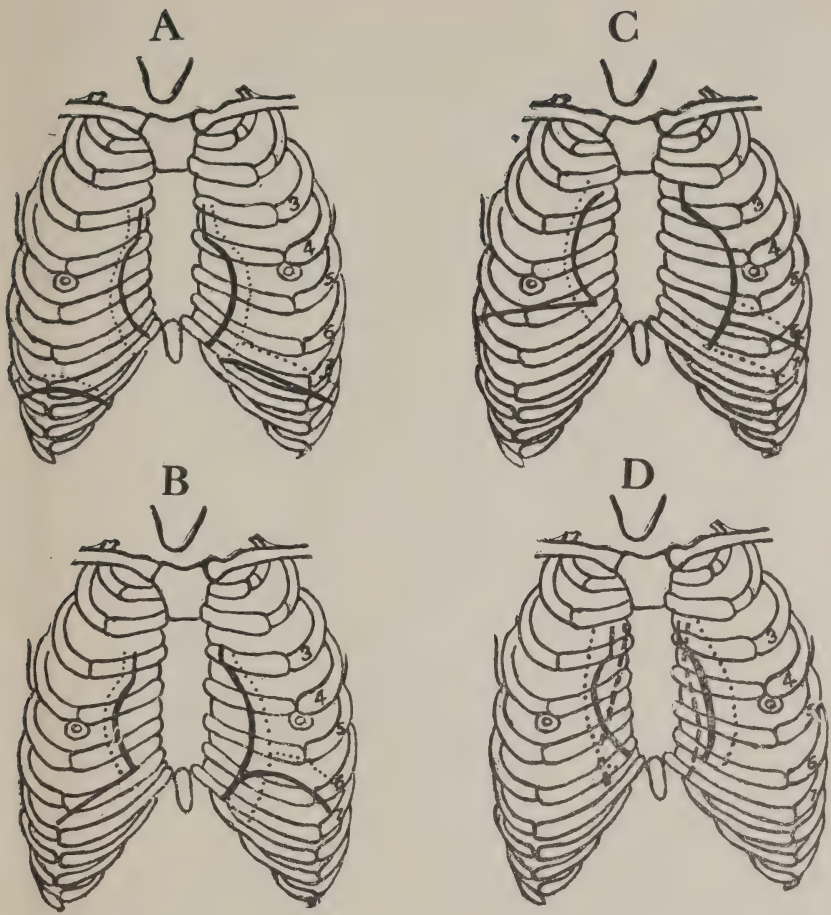


Fig. 9. — Fluoroscopic studies made by Drs. John W. Boyce and George W. Grier. Solid line indicates examination before, dotted line, immediately after, and line composed of dashes, examination a week after the race. A, small heart; contestant dropped out at one mile; B, heart right size; contestant finished No. 11; C, large heart, left dilatation; D, average case.

Relation of X-Ray Findings to Blood Pressure.

This work was carried out by Dr. John W. Boyce and Dr. George Grier with their assistants at the West Penn Hospital. They originally classified the cases examined before the race as (a) small hearts, (b) hearts of the "right size" and (c) large hearts. The average maximum blood pressure of the small heart cases was 124 mm., while the average of the hearts of the "right size" and large heart series was 138 mm. Of six cases that had

"small hearts," none finished the race. Of 17 that had hearts of the "right size" and large hearts, 10 finished. This means that with the compensatory hypertrophy there comes increased endurance. After the race, within three quarters of an hour in most instances, tracings of heart shadows were again made. The degree of dilatation varied.

The average fall in the cases of maximum pressure as a result of the race in those cases presenting a large degree of dilatation, was 31 mm., while the average fall of maximum pressures in those outlined as showing little change in the heart shadow was 12 mm.

Renal System.

Before Race.

The urine was examined in 24 cases. One showed less than 0.1 per cent of albumin, which was not of renal origin. There were no casts in any. On standing over night, crystals of calcium oxalate were deposited in five specimens.

Immediately After Race.

Amount: We succeeded in getting 19 specimens, and in those the total quantity excreted during the time of the race, which lasted between three hours and fourteen minutes to five hours. The largest amount was 220 c.c. and the smallest was 35 c.c.

Color: varied from normal to dark smoky amber; in several it was bloody.

Reaction: alkaline in those containing considerable blood, and in the others it was acid.

Specific Gravity: varied from 1012 to 1035. There was no ratio between the amount and the specific gravity.

Total Solids: These varied from 2.2 gm. to 13.51 gm. The presence of blood makes the estimation valueless. Even on eliminating the cases in which there was considerable blood in the urine, I could find no ratio between the solids and the loss of body weight during the race, nor to the total amount of urine.

Albumin: Every specimen showed albumin from mere trace to a heavy cloud.

Sugar: A positive reaction was not obtained in any case.

Acetone Bodies: Diacetic Acid: With ferric chlorid a typical reaction was obtained in 3 cases; it was distinctly present in 10, and in large amounts in 4 cases. It was absent in the case in which there was the largest amount of urine passed and present in small amount in the next largest specimen. Acetone: The acetone reaction was less marked, but present. Beta-oxybutyric acid was tested and found in one of the specimens. The nature of the diacetic and acetone reactions was verified by H. L. Amos of

the West Penn Hospital, to whom I am indebted for the examination of a number of specimens.

Microscopic Examination: Every one of the 19 cases showed casts; five of them showed "showers of casts." All but the largest specimen showed red blood cells; three showed large amounts of blood. In one specimen I found fat globules.

At Subsequent Periods.

Out of the 19 specimens examined at the end of a week, 4 showed light clouds of albumin and as many had casts. Two showed casts without albumin.

Three weeks after the race, 3 that did not show albumin before the race still showed traces of albumin and casts.

TABLE 23. URINARY FINDINGS BEFORE THE RACE, IMMEDIATELY AFTER AND AT SUBSEQUENT PERIODS.

	No. of cases.	Albumin.	Blood.	Casts.	Acet. Bodies.
Before	24	1	0	0	0
Immediately after	19	19	18	19	18
One week subsequent	19	4	0	6	0
Three weeks subsequent	..	3	0	3	0

RELATION OF CIRCULATORY TO RENAL SYSTEM (AS ESTIMATED BY URINARY FINDINGS.

Table 24 gives the age, maximum and pulse pressures before and after the race in the horizontal position; the amount of urine and approximate amounts of albumin and acetone bodies.

TABLE 24. RELATION BETWEEN CIRCULATORY AND RENAL SYSTEM (URINARY FINDINGS).

	Hor. B.-P. Before.		——Urine——		Hor. B.-P. After.		
Age.	Max.	P.-P.	C C.	Albumin.	Max.	P.-P.	Acet. Bodies.
18	140	..	220	I	100	..	...
36	140	..	205	I	110	..	...
25	145	..	200	½	130	..	...
27	122	32	195	I	110	25	I
19	122	..	195	I	110	..	...
18	122	..	190	III	96	..	...
?	115	..	190	II	88	..	...
?	120	32	175	I	120	32	II
31	138	..	170	II	92	..	...
36	132	22	170	III	88	? low	III
?	132	38	170	I	122	34	O
52	134	34	150	I	118	26	I
19	118	26	130	½	114	24	IV
25	110	20	125	I	110	15	I
20	115	..	120	I	98	..	...
20	115	..	75	III	130	..	...
21	135	45	35	III	108	..	...
23	135	45	?	III	100	20	I

From this table it may be seen that the subjects having the highest maximum pressures before the race excreted the largest

amounts of urine during the race. The pulse pressures were obtained in only part of this series, and their relation to the amount of urine seems variable.

Albumin was present in small amounts in the cases in which the larger quantities after the race were passed.

Albumin was present in largest amounts in those cases which showed the greatest fall in the maximum blood pressures; and in those which showed the most marked falls in the pulse pressures.

From these observations on the renal functions, it seems that the more serious the disturbance of the general circulatory system, the more marked are the evidences of this disturbance in the renal circulation, and this is evidenced by the amount of blood, degree of albuminuria and cylindruria.

As to diacetic acid, all considered, it seems that it was found in larger amounts in the urine from those who ran most successfully—i.e., those who ran hardest in the shortest time. Undoubtedly, many other factors play a part in this. The amount of acetone seemed small in proportion to the diacetic acid; one way to account for this is perhaps that it was largely eliminated by the respiratory effort.

Conclusions.

In the conclusion of this study, it may be said that the most marked changes which occur in the contestants who train for and compete in this race are as follows:

Before the Race.

The average individual who has trained for this race will, about the time he is in good training condition, have a pulse that is moderately slower than normal, with a normal diurnal variation. His blood pressure is higher than that of the average individual, and with this he has developed a compensatory hypertrophy. If in his case it is found that he has a greater than normal diurnal pulse variation, that will be associated with a higher than average blood pressure.

Or we may say that from these observations we are led to believe that the individual who has this more than average compensatory hypertrophy and higher blood pressure, will have a greater number of heart beats in the twenty-four hours. The average heart shadow as seen with the X-ray is larger than normal in nearly all cases, and some will show comparatively very large hearts. The subjects showing the larger hearts are the ones that have the higher blood pressures.

In the contestant who as a result of hard training, or because of some unknown preceding state of his heart, has developed a heart murmur, there will be found the very large heart and higher blood

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SUMMARY OF URINE TESTS

Finish	Distance	Time	BEFORE						IMMEDIATELY AFTER												SUBSEQUENT							SECOND SUBSEQUENT					
			Color	React.	Sp. Gr.	Alb.	Sugar	Microscopic	Amt. c. c.	Color	React.	Sp. Gr.	Solids	Alb.	Sugar	Acet.	Diac.	Microscopic	R. B. C.	W. B. C.	Color.	React.	Sp. Gr.	Alb.	Sugar	Date	Microscopic	Color	React.	Sp. Gr.	Alb.	Sugar	Microscopic
1		3.14																			a.	ac.	1022	0	0	6–26	r. l. ep. spermat.						
2		3.17																			a.	ac.	1020	0	0	7– 6	neg.						
3		3.19							75	v. d. a.	ac.	1030	7.2	III	0		III	quite m. gr. c. & hy. c.	few	few												
4		3.25	l.a.	ac.			0	cylind.													a.	ac.	1028	0	0	7– 4	neg.						
5		3.25	a.	ac.	1016	0	0	leuk.													p a.	ac.	1015	0	0	9d.	1 narrow gr. c.; uric ac.						
6		3.36							170	t. a.	alk.	1015	5.9	II	0		I	few gr. c.; fat globules														
7		3.36	a.	ac.	1018	0	0	leuk. shreds	170	v. d. a.	ac.	1018	7.1	III	0		III	showers n. hy. & few gr. c.	r. b. c.	w. b. c.	a.	alk.	1011	0	0	21d.	neg.						
8		3.40							220	t. a.	alk.	1022	11.27	I	0		0	gr. c. qu. num.	r. b. c.	w. b. c												
9		3.41							190	a.	ac.	1020	8.85	III	0		I	gr. & blood c.	r. b. c.	w. b. c.												
10		3.42							205	t. a.	alk.	1016	7.64	I	0		I	gr., hy., cellular c.	r. b. c.	w. b. c.												
11		3.44	d. a.	ac.				leuk.													p. a.	alk.	1012	l. cloudy	0	10d.	leuk. only						
12		3.50	a.	ac.		0	0	leuk. ca. ox.													a.	ac.	1021	0	0	9d.	leuk.						
13		3.53	a.	ac.		0	0	0													a.	ac.	1021	0	0	24d.							
14		3.57							200	a.	ac.	1029	13.51	½ of I	0		½ of I	showers hy., gr., cellular	0	0												
15		3.57	a.	ac.	1022	0	0														a.	ac.	1020	cloudy	0	9d.	no casts; few w. b. c.; ca. ox.	t. a.	ac.	1026	f. trace	0	uric acid (19 days after race)
16		3 57																														
17		3.58	d. a.	ac.			0	ca. ox. standing		d. a.	alk.	1020		III	0		I	broad & n. hy. c.	r. b. c.	w. b. c.	a.	ac.	1030	0	0	9d.	one hy. c.						
18		8.59							35	d. a.	ac.	1027	2.2	III	part ox.		III	showers n. hy. c.; cons. blood														
19		4.00	d. a.	ac.		0	0	ca. ox.	195	smoky v.d.a	alk.	1024	12.26	I	0		I	none seen; large amt. blood			p. a.	alk	1006	0	0	10d.							
20		4.15							120	d. a.	ac.	1035	9.78	I	0	red ring	II	showers hy. gr. tailed c.	r. b. c.	w. b. c.												
21		4.17																														
22		4.18	d. a.	ac.	1024 less than $\frac{1}{10}$	0	part ox.	cylind.													a.	ac.	1025	l. cloudy	0	10d.	cylind.; ca. ox.						
23		4.28																														
24		4.32	a.	ac.			0														a.	ac.	1022	0	0	8d.	few cylind.						
25		4.15																														
26	24.85	4.10																														
27	R. 18+W. 6.75	5.00	a.	ac.			0	shreds leuk.	130	a.	ac.	1025	7.57		0		IV	none found	few r. b. c.		a.	alk.	1021	0	0	10d.							
28	24.85	4 15							190	d. a.	ac.	1026	1 .5 1	II.	0	oxybutyric	I	narrow hy.	r. b. c.	w. b. c.												
29	20	3.03																														
30	18	3.04	a.	ac.	1022		0		125	d. a.	ac.	1024	6.9	I	0		I	hy., gr. cyl.	few w. b. c.		a.	ac.	1016	0	0	10d.							
31	17																															
32	15	2.30	a.	alk.		0	0		150	d. a.	ac.	1024	8.3	v. l. cl.	0		I	many n. & broad hy. c.	r. & w. b.c. ca.ox.		a.	ac.	1022	0	0	10d.	hy. c. & cellular	a.	ac.	1020	f. trace		1 hy. c.
33	15																															
34	15	2.00																														
35	15	2.00								a.	alk.	1025		I	0		II	showers hy., gr. & blood c.	some r. b. c.												
36	15	2.25																														
37	12																															
38	11½	1.40	d. a.	ac.		0	0	leuk.													d. a.	ac.	1025	l. cloudy	0	10d.	neg.; 2 exams.						
39	11	2.00	l.a.	ac.	1023	0	0	cylind.																								
40	11	1.40	l.a.	ac.		0	0	ca. ox.													p. a.	alk.	1014	0	0	10d.	1 mucous cast	a.	ac.	1010	0	0	1 hy. & 2 cellular c.
41	18	2.38	l.a.	ac.		0	0		170	a	alk.	1012	4.75	I	0		0	many blood & gran. c.	r. b. c.	w. b. c.												
42	11	1.25																														
43	10	1.30	p. a.	ac.		0	0	0	175		alk.	1021	8.56	I	0		II	qu. num. gr. & hy.	r. b. c.	w. b. c.	p. a.	ac.	1010	0	0	10d.							
44		1.30																														
45	$3\frac{7}{10}$	1.25																														
46	16	?																														
47			a.	ac.	1020	trace	0	0																								
48			a.	ac.	10	0	0	0																								
49			a.	ac.		0	0	0																								
50			a.	ac.		0	0	0																								
51	13																															
52	24		a.	ac.	1021	0	0				ac.	1026		I	0		0	few n. hy. c.														
53	12																															
54	15																															
55	24																															

pressure. Body overweight, laborious occupation, short and severe training are productive of higher than average blood pressures and associated hypertrophy.

After the Race.

As a result of this inordinate exertion, if he is of the average class, he will have a fall of about 20 per cent in his blood pressure; if he is of the "heart-murmur cases," he will have a still greater fall in his blood pressure. If his heart shadow with the X-ray shows a marked increase in size (much dilatation), his blood pressure will have a greater fall than if his heart shadow remains about the same size (slight dilatation).

At the end of six months the blood pressure is still nearer the normal level than at the previous examination.

Most of these contestants had been running during the preceding six or nine months, and it is natural to expect a gradual disappearance of the established hypertrophy, as our findings bear out.

The change of posture from the horizontal to the erect is followed by certain accommodative changes in the blood pressures, these depending largely on the reserve energy of the circulatory system, and the promptness with which it reacts to the force of gravity.

The effect of this severe bodily exertion on the kidneys is definitely proportionate to the degree of general circulatory disturbance, of which the renal circulation is part.

In these studies we have had the rare opportunity of observing the transition stage from health to disease. Beginning as physiologic changes many of these cases have transgressed the dividing zone entering into that of the pathological. The exciting factors once removed, a recession into the normal followed, in some cases reaching the physiological quickly, others slowly, while some, it may be, will never return to normal.

Bibliography; Selected from Hirschfelder's Diseases of the Heart and Aorta. 1910.

McCurdy, J. H. Effect of Maximal Muscular Effort on Blood Pressure, Am. J. Physiol., Bost., 1901, v., 95.

Masing, E. Ueber das Verhalten des Blutdrucks des jungen und des bejahrten Menschen bei Muskelarbeit. Deutsch, Arch. f. klin. Med. Leipz., 1901, lxxiv., 253.

Gordon, G. A. Observations on the Effect of Prolonged and Severe Exertion on the Blood Pressure in Healthy Athletes. Edinb. M. J., 1907, xxii., N. S. 53.

Tangl, F., and Zuntz, N. Ueber die Einwirkung der Muskelarbeit auf den Blutdruck. Arch. f. d. ges. Physiol. Bonn., 1898, lxx., 544.

Kaufmann, M. Recherches experimentales sur la circulation dans les muscles en activité physiologique, Arch. de Physiol. Par., 1892, 5 ser., iv., 278.

Bowen, W. P. The Pulse Rate as Modified by Muscular Work. Contrib., Sc. Med., dedicated to V. C. Vaughan, Ann Arbor, 1904.
Hough, Th. On the Physiological Effects of Moderate Muscular Activity and of Strain. Science, Lancaster, 1909, N. S., xxix., 484.
Blake, J. B., and Larrabee, R. C., Scannell, D. D., Tileston, W., Emerson, W. R. P., Strong, L. W., and Conolly, J. M. Observations upon Long-Distance Runners. Bost. M and S. J., 1903, cxlviii., 195.
Dietlen, H., and Moritz, F. Ueber das Verhalten des Herzens nach langdauernden und anstrengenden Radfahren. München. med. Wchnschr, 1908, lv., 489.
Bruck, E. Ueber den Blutdruck bei plötzlichen starken Anstrengungen und beim Valsalva'schen Versuch nebst Bemerkungen über die hierbei eintretenden Veränderungen der Herzgrosse. Deutsch, Arch. f. klin. Med., Leipz., 1907, xc., 171.
Williams and Arnold. Effect of Violent and Prolonged Muscular Exercise on the Heart. Philadelphia Med. Jour., 1899, iii., 1233.
Potter, N. B., and Harrington, J. T. Medical Supervision of Athletics Among Boys at Boarding Schools. Jour. Am. Med. Assn., 1909, liii., 1957.

Finishing Number
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GENERAL SUMMARY

Finishing Number	Age	Height	Weight	Before Races —or+	Occupation	Work Hours	Habits	Athlete in Runs	Meat	Vegs.	Liquor	Wt. Lost Lbs.	Previous Runs Marathons	Training Pulse Dist.	Training Pulse A.M.	Training Pulse P.M.	Day Prev. Temp. MO.	Day Prev. Temp. R&C.	Heart	Blood Pressure Pulse H.	Blood Pressure Pulse S.	Blood Pressure Horizontal S.	Blood Pressure Horizontal D. P.P.	Blood Pressure Erect S.	Blood Pressure Erect D. P.P.	Before Race Eat and Drink	During Race Eat and Drink	During Race Cramps	After Race Heart	After Race Temp MO.	After Race Temp REC.	After Race Loss in Weight	After Race Pulse H.	After Race Pulse S.	After Race H. Blood P. S.	After Race H. Blood P. D. P.P.	After Race Erect B. P. S.	After Race Erect B. P. D. P.P.	Subsequent Examinations Pulse H.	Subsequent Examinations Pulse S.	Subsequent Examinations H. Blood P. S.	Subsequent Examinations H. Blood P. D. P.P.	Subsequent Examinations Erect B. P. S.	Subsequent Examinations Erect B. P. D. P.P.	Weight Gained	LAST EXAMINATION Pulse Hor. Erect	LAST EXAMINATION Horizontal S.	LAST EXAMINATION Horizontal D. P.P.	LAST EXAMINATION Erect S.	LAST EXAMINATION Erect D. P.P.	X RAY Sphygmo. B.P.	X RAY Before	X RAY Sphygmo. B.P.	X RAY After	X RAY Subsequent
1	22	5-4½	128	9½	Professor	9	Good	3 yrs.	2	0	0	4	3				99°	100°	Negative	77	105					Light	0	0	0	99°	102°	3½	114	133	132	112	20	105	90	15	Sitting	84	115	85	30			2 lbs. in 1 day														
2	22	5-3	122	11½	Clerk	9	Good	10 yrs.	¼	0	0	3	1	12	⅞	⅞	98½	99½	Muff. Apex 1st sound	60	125					F. Light	0	"Stomach"	Weak and Intermittent	97½	100½	4½	100	120	115				58	56	128	95	138	100 38	4 lbs. in 15 days													1 wk. later showed most extreme dilat. of any
3	20	5-3	115	8¼	Light Work	10½	Good	1 yr.	2	0	0	0	1 mar. 315-mile				99½	100½	0	72	112					F. Light	0	8th Mi. Rt. Lung	Syst. Base	97°	100°	4½	108		130																			1 wk., recov. to less than 1st shadow.
4	18	5-4	132	1	None		Good	1 yr.	2	3	0	12	3	12	72	68	99°		S. Apex	72	72	110	90	20	115	80	35	Meat	Both	For S Mi.	Syst. Apex	99°	101°	4½	93	112	95	88	7	98	90	8	50	52	125	88	37	130	95	35	3¼ lbs. in 9 days	66	74	120	86	34	110	85	25	110		right		95		dilat.	1 wk., later, outline narrower, slightly to its original size.
5	28	5-8½		2	Drayman	Night	Alcohol	1 yr.	3	0	0	7	2					99½		105	97	132	98	34	128	95	33	Light	1250 cc.	0	Syst. Apex		104		128	135	95	80	15	90	?	..	78	80	119	90	29	120	90	30	2½ lbs. in 9 days	72	82	110	84	26	110	82	28	132		right (dilat.)?		95		left dilat.	
6	31	6-	180	8½	Laborer	D. and N. Alternate	Good	1 yr.	0	0	0	15	1	18	48	67	98°	100°	Negative	71	138					Light	0	0	0																													
7	36	5-5½	148	9½	Puddler	N. & D.	Too much Meat and Water, 6 qts.	1 yr.	3	0	0	7	1	3	55	65	....	99°	S. Apex	63	76	132	100	32	132	100	32	Light	V. Light	Little Rt. Side	0	97°	102°	5½	112	120	88	?	..	88	?	..	64	90	124	87	37	118	100	18																
8	18	5-8	133	13½	Laborer		Good Vegetarian	1 yr.	0	0	0	6	1				100½	101½	0	84	140					V. Light	1 Orange	0	0	97°	100°	1½	84		100																									
9	18	5-4		2			Meat t. i. d. Good	1 yr.	3	Cigars 15	0	0	1 mar. 7 others				99°	100°	0	84	122					V. Light	2 Oranges 3 Raw Eggs	0	0	100	102°	1½	72		96																									
10	26	5-5	135	22		9	Good	1 yr.	1	¼	0	5	4	3	70	78	98°	100	0	69	140							0	97°	100°	1½	75	88	110																									
11	19	5-7	150	12		14	Good	1 yr.	....	0	0	9	3				....	100°	0	78	90	120	85	35	120	80	40	Light	V. Light	Leg	0	100	100°	0	112	112	100	70	30	108	75	33	62	80	120	85	40	130	100	30	3 lbs. in 10 days							120	right	100	excessive dilat.	1 wk., recov.; pul., art., & left auricle smaller than 1st ex.
12	21	5-2	132	3½	Coachman	16	Meat t. i. d. Good	1 yr.	3	0	0	8½	5				99°	....	S. Pulm.	76	80	145	100	45	140	105	35	F. Light	V. Light	0	0	0	97	99½	6	100	108	108	80	28	106	80	20	68	74	Murmur After Pacing 152 100 52		152	100	52	6½ lbs. in 10 days	72	78	122	98	24	122	90	32	145		large		108		left sided dilat.	in 1 wk., original size
13	22	5-4	132	8½	Merchant	8	Good	1 yr.	1	0	0	3	3		60	65	100°	....	0	74	76	125	100	25	122	100	22	Light	Water	Abdomen	0	98	99°	3	96	100	94	74	20	92	80	12	63	66	110	75	35	110	80	30	3 wks.							145		right					
14	25	5-7	142	8½	Laborer	9½	6 qts. H_2O Good	1 yr.	2	0	0	4	3				100	101¼	0	80	145					Heavy	Heavy	0	0	99°	102°	2½	100		130																									
15	18	5-8	133	11½	Clerk	8	Good	1 yr.	2	0	0	3	2				99°	....	0	84	84	110	90	20	118	85	33	V. Light	0	0	0	100°	101¾	4½	104	120	105	80	25	110	75	35	52	70	120	95	25	122	92	30	4½ lbs. in 10 days							110	right + +	105	dilat. both sides	
16	35	5-9	165	6½	Teamster	10½	Good	11 yrs.	1	3	0	12	3				99°	100°	0	66	135					V. Light	0	0	0	97°	98°	4	88		110																									
17	23	5-8		7½	Light Labor	8	Good	1 yr.	2	0	0	0	1 modified mar.					100°	0	106	106	135	90	45	135	100	35	V. Light	V. Light	Once, Rt. Side	0	98½	100°	4	106	116	100	80	20	88	75	13	73	90	118	80	38	120	90	30	1½ lbs. in 9 days							135	med. or $\frac{n}{i}$	100	dilated	
18	21	5-7½	143	5½	Electrician	10	Good	1 yr.	1	0	Ale 1	10	0	5	60	74	100°	100°	0	96	135					Light	V. Light	0	0	99°	101°	4½	100	112	108																									
19	27	5-3	128	8½	Bank Clerk	8¼	Good	9 yrs.	5x 3d	2	0	3	0				100		0	66	76	122	90	32	118	90	28	Light	0	0	0	99	100	5½	93	114	110	85	25	100	85	15	48	52	130	100	30	138	98	40	6 lbs. in 9 days												
20	20	5-5	144	8	Teamster	10	Good	1 yr.	1	4x 51	0	8	3 15-mile				100	100°	0	94	115					Heavy	0	0	0	98°	99°	4	94	110	98																									
21	22	5-6	124	16½		12	Good	1 yr.	2x	0	0	3	1				99	99°	0	96	130					0	V. Light	0	0	99	102	2	96		130																									
22	21	6-1½	158	13		12	Good	1 yr.	1	0	0	23	1	0	80	83	100	100	30	132	110	22	Light	V. Light	0	0	0	100	100°	1½	90	96	100	82	18	85	70	15	72	90	138	90	48	128	98	38	7½ lbs. in 9 days							130	right (dilat. to left)	100	more dilat. to left	
23	25	5-11½	175	6½	H. Laborer	8	Not Good	1 yr.	3	0	0	0	10	Short Dist.			98°	99°	0	62	130					Light	0	Right Ribs	0	97	102	8½	92		116																									
24	27	5-3		5½	H. Laborer	8	Good	9 yrs.	2	0	0	0	4				99°	....	0	67	72	120	95	25	120	100	30	V. Light	0	0	0	98°	99°	2	80	93	110	72	38	105	80	25	78	76	120	90	30	120	90	30	3½ lbs. in 9 days							120(a)	right +	110	no change; diaph. higher	
25	34	5-6	128	14			Good	20 yrs.	1	4	0	0	6	8				....	0	82	135					V. Light	0	0	0	99	100°	1½	84	112																									
26	19	5-7	132	12½	M. Labor	5	Good	1 yr.	1	0	0	5	1	8	54	64	99	101	0	92	120					V. Light	V. Light	0	0	98°	102°	3½	140		102																									
27	19	5-9	141	5½	V. L. Labor	10½	Good	1 yr.	2	0	0	4	3	2	58	58	....	99	0	54	74	118	92	26	112	92	20	Heavy	0	Abdomen	0	97°	100°	+1	80	116	114	90	24	108	90	18	66	54	135	88	47	120	92	..	½ lbs. in 9 days	54	78	106	84	22	112	90	22	118		right		114		dilat. + w.	1 wk., outline less than 1st; diaph. rev.
28		5-10	141		Clerk		Good	1 yr.	0	0	0	0	4½	1				99°	100°	0	72	115								0	99	102				64	72	88																									
29	19	5-5	122	8½	Clerk	6½	Good	2 yrs.	1	0	0	0	2	5	65	70	99	100°	0	72	120					Light	Much Water	0	Irregular	95°	99°	3½	62		110																									
30	25	5-6	140	11	H. Laborer	D. & N.	10½ Good	1 yr.	3	0	0	0	8	2				100	0	65	70	110	90	20	112	98	14	V. Light	Orange and Water +	0	0	0	95°	100°	4	81	96	110	95	15	110	92	18	56	58	112	92	20	112	92	20	3½ lbs. in 9 days							110	small	110	bigger	1 wk. later, outline bigger
31	22	5-4	122	14	H. Laborer	10	Meat t. i. d. Fair	1 yr.	3	0	0	0	7	2				99°	100°	0	64	115					Heavy		+	0	98°		1	96		115																									
32	52	5-6	151	6	Mechanic	11	Good	1 yr.	1	0	0	7	2	3	56	68	99°	....	0	82	78	134	100	34	138	100	38	Light	0	0	0	98°	100°	1½	106	129	118	92	26	108	90	18	60	66	128	98	30	112	92	20	½ lbs. in 20 days							134	good size	118	excessive dilat. 1 hr. later	1 wk. later, not restored to former size
33	18	5-9	135	13	M. Laborer	10	Good	1 yr.	1	0	0	5	0						0	80						Light		+	0			2½	120																									
34	20	5-7	150	2	M. Laborer	9	Good	1 yr.	2	0	0	7	5	5	52	53	....	100°	0	60	140					Heavy	0	0	0	100		1½																									
35	29	5-6	145	3½	Clerk	9	Good	1 yr.	1	2	0	8½	1	3	60	62	99°	100°	0	78	122					Light	0	Si Pain in Side	0	98		1½	108																									
36	25	6-	168	6½	H. Laborer	9	Vegetarian Good	1 yr.	0	0	0	0	8	0	13	50	70	99°	100°	0	54	150					0	0	0	0	97	98°	2½	80																									
37	18	5-6	140	6	Laborer	10½	Good	1 yr.	1	0	0	0	10	3				97½	100	0	68	125					Light			0	97		3½	96																									
38	21	5-7	128	4½		8	Fair	1 yr.	2	10	Beer ¾	8	2				100°		0	69	76	124	95	29	120	100	20	Light			0	98°	99°	6½	81	99	80	75	5	95	80	15	56	52	110	88	22	110	78	32	5½ lbs. in 9 days							124	right	80		
39	19	5-5	155	25			Fair	1 yr.	¾	0	0	0	2						100	S. Apex	Base	87	84	155	130	25	142	118	24				1	99	99°	0	108	120	92	78	14	82	72	10																			155	small	92	dilat. more than ¼ former size (11 miles)	1 wk., smaller
40	23	5-5	130	5	H. Laborer	12	Only Fair	1 yr.	3			0	5	3				99		0	66	66	133	110	23	135	100	35	V. Light	0	0	0	99°	101°	1½	114	135	108	88	20	108	88	20	66	62	125	100	25	132	100	32	2½ lbs. in 9 days							133(a)	right +	108	no change	
41		5-5		5														99°		0	64	64	130	92	38	132	90	42				0	95½	97°	½	90	81	122	88	34	130	100	30																			130		122		
42		5-7	145	6½														99°	101	0	100	145					V. Light	0	0	0	0	97°		1	92		118																									
43	29	5-3	120	$\frac{n}{i}$	M. Baker	9	Fair	1 yr.	1	4	0	1	1				100	....	0	75	76	120	88	32	100	80	20	Light	0	0	0	0	99°	98°	+2 Water	92	110	120	88	32	100	80	20	III. II. I Irregular 56		118	88	30	Regular Erect 110	90	20	−1 lb. in 9 days							120	small (dilat. right)	120	no change	1 wk., slight change
44																		99°	100°	0	76	120								0	98°	99°	3½	90		115																									
45	29	5-7	146	$\frac{n}{i}$	Mechanic	10½	Good	11 yrs.	1	0	0	2	1				99°	100°	0	74	115					V. Light	0	0	0					1	108																									
46	23	5-4	114	10½	Farmer	14	Good	6 yrs.	2	0	0	0	1				99°	100°	0	68	120					Light	0	Stomach	0																													
47	29	5-9½	150	2½		8	Eating Bad	1 yr.	2	0	0	0	2	1	5	66	74	....	99°	S. Apex	83	85	162	112	50	150	105	45	Light	0	0	0																															
48	27	5-5½	140	5	Milkman	12	(3 pts. Beer) Fair	1 yr.	P. & S. 15		Beer ¾	0	4	12		75	100				62	72	130	100	30	120	100	20	Light	0	0	0																															
49	27	5-7	123	18			Fair	1 yr.	1	0	0	0	3					99°		72	70	130	95	35	132	100	32																																	
50	21	5-5	126	1½			Fair	1 yr.	0	0	0	0	4							Arryth.	70	70	105	85	20	110	85	25	Light																															
51	18	5-8	148	2	H. Laborer 120 P.	12	Fair	1 yr.	2	¼	0	2	1								76	83	118	95	110	95	15																															
52	21	5-7	145	8	Driver, Coal Mine	9	Fair	1 yr.	1	4	1	9	3				99°	100			76	124					Light	0	0	0																													
53	24	5-3+	121	5	Machinist	13	Fair	1 yr.	2	¼	0	0	8					99°	100°	Negative	68	120					Ham	0	Cramps																													
54	26	5-10+	164	3		9	Fair	2 yrs.	3	0	3	4	4					99°	100°		84	130					V. Light	0	0																													
55	19	5-4	125	1	Student		Tobacco	1 yr.	2	Many	0	6	7				98	99°	Hyper.	72	120	Gen. cond poor				F. Light	0	0																													

Small = relatively small.
(a) = largest hearts.